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ORIGINAL ARTICLES.

I.—On some new Devonian Fossils.

By Prof. T. Rupert Jones, F.R.S., and Dr. H. Woodward, F.R.S.

(PLATE XI.)

I. Echinocaris Whidbornei. Plate XI. Fig. 1.

In this specimen one valve (the left) and a part of the dorsal region of the other, remain visible; the rest of the right valve being bent down, broken, and imbedded in the matrix. This is a finely micaceous, non-calcareous, grey mudstone, weathering ferruginous towards one edge, which probably abutted on a crack open to water and atmosphere.

The fossil, in the grey portion is darker than the matrix, and fairly represents the test of half of the carapace, with only a very thin lamina wanting, a broken edge of which is traceable (with a lens) near the ventral margin. This left valve measures 9·2 by 7·4 mm. It is subcircular, more boldly curved on the ventral than on the posterior margin, whilst the front margin is somewhat truncate, having a nearly straight edge from above downwards before it bends round into the ventral curve. The dorsal border was probably straight along two-thirds of its length, but has been crushed against the other valve and somewhat distorted. A distinct, narrow, marginal rim is present,—thickened and raised on the front margin, and flatter on the ventral and hinder margins.

The convexity of the surface is interrupted by several elevations and depressions. In the antero-dorsal region are five unequal swellings; one, large and pyriform, is most noticeable, and a small subtriangular swelling in front of it fills the antero-dorsal angle; behind these a triangular space is occupied by three other unequal prominences; and altogether these represent the locality of the important cephalic (buccal or gastric) organs, and their muscular attachments.

Behind the swellings are two ridges on the valve; one along its median line, and the other, parallel, but somewhat curved, on the ventral region. The swellings are each ornamented with a few small tubercles, somewhat wide apart. The ridges also bear such little tubercles; the upper (straight) ridge having about nine, and the lower (curved) ridge has six.

This fossil belongs evidently to *Echinocaris*,[1] Whitfield (1880);

[1] For the latest account of this genus and the several species here mentioned, see Geol. Surv. State of New York, Palæontology, by Prof. James Hall and J. M. Clarke. vol. vii. 1888, pp. 166-181, plates 28-30. See also our Sixth Report (for 1888), Rep. Brit. Assoc. 1889, p. 180.

but it differs from *E. punctata*, Hall (fig. 2, after Beecher, about two-thirds of the natural size), in being rounder behind, and truncate in front,—in the arrangement of the cephalic prominences, —and particularly in having two parallel ridges, instead of one sigmoidal ridge. So also it differs from *E. sublævis*, Whitfield, *E. condylepis*, Clarke, *E. multinodosa*, Whitfield, and *E. Whitfieldi*, Clarke. *E. pustulosa*, Clarke, has only one tuberculate ridge. *E. socialis*, Beecher, has the two parallel ridges, and the valve is slightly pustulose here and there; but it is smaller and more ovate than the specimen under notice; and the cephalic swellings, though analogous, are not identical.

As it is evidently a new species we propose to name this unique fossil from Devonshire Echinocaris Whidborne, after the Rev. G. F. Whidborne, F.G.S., who drew our attention to the specimen, and first recognized its true affinities.

Mr. J. E. Marr, Sec.G.S., informs us that this rare fossil was found by Mr. Dufton in the leaden-blue shales of the *Lingula-squamiformis* beds in a quarry near Sloly, close to the three-milestone on the Barnstaple and Ilfracombe road. The shales (he adds), which are here interstratified with very micaceous frilled sandstones, belong to the Cucullæa-zone of the Marwood Beds. The specimen is preserved in the Woodwardian Museum, Cambridge, and has been kindly lent to us by Prof. T. McKenny Hughes for examination and description.

II. Beyrichia Devonica, sp. nov. Pl. XI. Figs. 3–5.

Figs. 3, 4, 5 show internal casts of some large *Beyrichiæ* from the Devonian strata near Torquay, in Devonshire, in different states of preservation. Nine or ten other such specimens were sent to us for examination by Thos. Roberts, Esq., F.G.S. They are all preserved in the Woodwardian Museum, Cambridge, and are imbedded in a finely micaceous, purplish-grey, schistose mudstone, weathering red, from the New Cut, above Meadfoot, Torquay. The fossils occur, sometimes on a cleavage-plane, more frequently on the bed-planes, compressed and distorted by pressure; and therefore rarely (as Fig. 3) escape some such modification. The test of the valves has gone, and the casts and moulds are both coated with ruddle, which in some cases seems to represent the test.

Figs. 3*a*—*e*. This is the internal cast of a simple three-lobed *Beyrichia* (4 mm. long, by 2 high), having, in the curved ventral junction of the two hinder lobes, some analogy to both *B. Buchiana*, Jones, and *B. Klædeni*, var. *antiquata*, Jones,—which are of Upper Silurian age. In the shape and size of the valve, however, and the proportions of the lobes, it differs from both. Another good cast (6 × 2·5 mm.) differs slightly from Fig. 3, appearing sharper in front and blunter behind, if looked at on edge,—that is, the anterior lobe is rather further from the front margin, and the posterior lobe nearer to the hinder margin.

The impression from out of which some of these and other casts have come indicate no other characters of the surface except what

the casts show; in some cases, however, the marginal rim is more distinct.

Figs. 4 *a*—*d*. These show the cast of a very large and much squeezed carapace (7·5 mm. long; the hollow mould is 8 mm., having more marginal rim behind). The valves have been lengthened and compressed (Figs. 4 *b*, *c*), the lobes stretched obliquely, and the curved ventral junction obliterated (Fig. 4*a*). The results of pressure and the lower scale of magnifying give this specimen an appearance very different from that of Fig. 3.

Figs. 5 *a*, *b*, show a neat and smaller cast (3 mm. long) of the same species, but modified by pressure (from above downwards and obliquely), so that the length of the valve has been increased, the height lessened, the lobes thrown into an oblique position (as also seen in Fig. 4*a*), the ventral curve almost obliterated, and by a longitudinal wrinkle or small fold (not well shown in Fig. 5*a*) the large pyriform lobe is puckered all along its postero-ventral region. The result of these changes is that the modified valve looks almost like a variety of *B. Klœdeni*, M'Coy; but the evident effects of pressure are all that separate it from the more typical forms, such as Fig. 3.

As a new species we propose to call this form BEYRICHIA DEVONICA.

As is well known, Prof. Dr. Ferdinand Roemer some years ago noticed a large *Beyrichia* (about 4 mm. long) from the Devonian rocks of the Bosphorus.[1] See his "Geognost. Bemerk. auf einer Reise nach Constantinopel," etc. "Neues Jahrb." 1863, p. 521, pl. 5, figs. 8*a*, *b*. At p. 509 F. Roemer referred these fossiliferous rocks to the Middle and Upper Devonian; but M. de Verneuil (Bullet. Soc. Géol. France, 2 sér. vol. xxi. (1864), pp. 147–155) regarded them as of Lower Devonian age. In the GEOL. MAG. Vol. VIII. (1870), p. 466, Prof. Dr. Ferd. von Hochstetter is cited as referring[2] them palæontologically to the horizon of the Lower Devonian beds of Western Europe, noting also that they contain some few Upper Silurian fossils.

Roemer's two little figures unfortunately do not allow us to offer an opinion as to the specific characters of his *Beyrichia* from the Bosphorus.[3] It may or may not be related to our species from Torquay.

The new *Beyrichia* from Devonshire has been alluded to in the Ann. Mag. Nat. Hist. ser. 6, vol. ii. 1888, p. 299, by the Rev. G. F. Whidborne, F.G.S., and is there said to have been found by Mr. T. Roberts, Mr. Solly, and other members of Professor T. McKenny Hughes's Cambridge party during their visit to Torquay in the

[1] The Turkish *Beyrichiæ* above mentioned are briefly noticed also by Mr. W. R. Swan, in the Quart. Journ. Geol. Soc. vol. xx. (1864), p. 115.

[2] In his Geological Conditions of the Eastern Part of European Turkey, Jahrb. der K.K. geol. Reichsanstalt, vol. xx. 1870.

[3] This specimen, collected by M. A. Dumont, was sent to Dr. Ferd. Roemer by M. G. Dewalque, who, having the care of the Museum of the Liége University, has allowed us to see the specimen. It is closely allied to, if not the same as our *B. Devonica*.

spring of 1888, in the red beds of the "New Cut" or "Lincombe-Hill Drive," from which the late Mr. Champernowne obtained his *Homalonotus* some years ago.[1] These beds lie high upon the slope of the Ilsham Valley, some hundred yards to the North of Meadfoot Bay. They are considered by Prof. Hughes to be the same as, or, more probably, slightly lower than the *Pleurodictyum*-beds of Kilmorie; and he has obtained *Pleurodictyum* and other fossils from beds in their immediate neighbourhood.

EXPLANATION OF PLATE XI.

FIG. 1. *Echinocaris Whidbornei*, sp. nov.
FIG. 2. *Echinocaris punctata*, Hall; after Beecher, about $\frac{2}{3}$rds.; shown for comparison, and to indicate the form of the whole animal.
FIGS. 3–5. *Beyrichia Devonica*.

II.—On an Ichthyosaurian Paddle Showing the Contour of the Integuments.

By R. Lydekker, B.A., F.G.S., F.Z.S., etc.

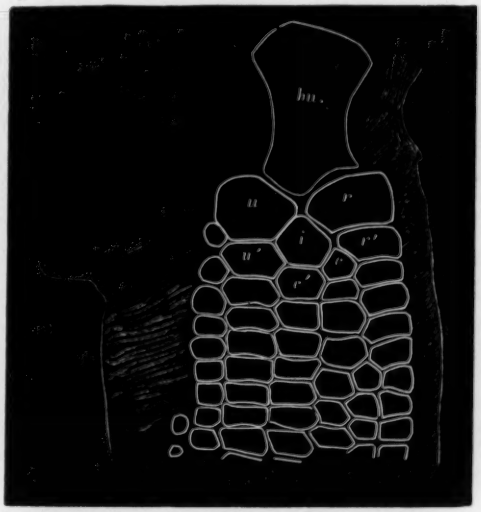
In the year 1841 Sir R. Owen described and figured[2] a slab of rock from the Lower Lias of Barrow-on-Soar which showed the impressions of the bones and integuments of a pelvic paddle of an *Ichthyosaurus*, probably referable to the typical *I. communis*. In this specimen[3] it appears that the integuments were produced to a greater extent on the posterior than on the anterior side of the bony framework; and that while the anterior margin of the soft parts showed evidence of squamation, the larger posterior flap was marked by oblique striæ extending from the bones to the periphery which appeared to have been caused by parallel bundles of muscular fibres. The distal extremity of the soft fin terminated in a sharp point far below the distal bones.

This specimen appears to be the only English example hitherto described showing the form of the integuments of the paddles. In 1888, however, Dr. E. Fraas published a paper on the integuments of the paddles of *Ichthyosaurus*,[4] in which he described two specimens belonging to the Longipinnate[5] group of the genus, which may apparently be referred either to *I. acutirostris* or the allied *I. Zetlandicus*. One of these specimens showed both the pectoral and pelvic paddles, while the second only exhibited the pectoral paddle, which is figured in the plate accompanying the memoir. These specimens confirmed the inferences drawn from the English example, but showed that in the Longipinnate group the integumentary portion of the paddles was relatively wider, and terminated in a blunt lower extremity, which extended but a short distance beyond the distal

[1] Geol. Mag. 1888, pp. 487–491, Pl. XIII.; 1882, pp. 157–8, Pl. IV. Fig. 3.
[2] Trans. Geol. Soc. ser. 2, vol. vi. pt. i. p. 199, pl. xx. See also Liassic Reptilia (Mon. Pal. Soc.) pt. iii. pl. xxviii. fig. 3.
[3] British Museum, No. 29672.
[4] Jahresh. Ver. Nat. Württemberg, 1888, pp. 280–303, pl. vii.
[5] See the writer's Catalogue of Fossil Reptilia and Amphibia in British Museum, pt. ii. p. 69 (1889).

bones. They also showed that the pectoral limb had a broad flap of integument in the axillary region. Oblique striæ, like those of the English specimen, were observed on the posterior flap of integument, and were likewise held to be probably formed by muscular bundles; while the squamation of the anterior border of the fin was shown to be of a very minute and fine structure.

So far as I know, the above is all the original literature which has appeared on this subject, and I proceed to notice the specimen on which the present communication is based. The specimen in question was kindly sent to me by Mr. Montagu Browne, of the Leicester Museum, who obtained it some time ago from the Lower Liassic quarries at Barrow-on-Soar. It consists of a split slab showing the imperfect thoracic region of a small Ichthyosaur clearly



Ventral aspect of the imperfect left pectoral paddle of *Ichthyosaurus intermedius*; from the Lower Lias of Barrow-on-Soar.
Half nat. size. *hu.* humerus; *r.* radius; *u.* ulna; *r'.* radiale; *i.* intermedium; *u'.* ulnare; *c. c'.* centralia.

referable to the Latipinnate group of the genus, and apparently belonging to *I. intermedius*. A large portion of the left pectoral limb is well preserved, the bones having been split in a plane parallel to the dorsal and ventral surfaces; although the distal extremity is unfortunately wanting. The half of the slab which best exhibits the paddle is the one in which, if the specimen were not split, we should look upon its ventral aspect; this view being represented in the accompanying woodcut. An inspection of this figure shows that the lateral flaps of integument are clearly marked on the slab, and that their general arrangement is the same as in the specimens previously described. On the narrow anterior flap a minute squamation can be detected with the aid of the

lens; while the wider posterior flap shows the oblique lines described by Messrs. Owen and Fraas. These lines are formed by whitish films lying on the rock, which are distinctly striated, and are at first sight very suggestive of fin-rays, although it is on the whole more probable that they really indicate parallel muscular bundles. The axillary region was evidently produced into a well-marked flap, or prominence. In proportion to the bony framework the posterior flap of integument is much narrower than in the specimen figured by Fraas; and since our specimen agrees in this respect with the pelvic paddle figured by Owen, it may be assumed that the distal extremity of the soft part was produced and pointed as in the latter.

We have, therefore, now good evidence that while the integuments of the paddles of the two primary groups into which the genus *Ichthyosaurus* is divided were of the same general type of structure, yet that they differed so markedly in detail as to afford another important point of distinction between the two groups.

I may add that Mr. Montagu Browne has been good enough to present the figured half of this interesting specimen to the British Museum.

III.—On the Origin of the Stone-Rivers of the Falkland Islands.

By Charles Davison, M.A.,

Mathematical Master at King Edward's High School, Birmingham.

THE stone-rivers of the Falkland Islands have been described by Mr. Darwin, Sir Wyville Thomson, Dr. Coppinger, and other naturalists who have visited those regions.[1] The accounts given by the two first-named are well-known and easily accessible, and render a full description here unnecessary. But it may not be out of place to summarise the principal features of the stone-rivers, which must find an explanation in any satisfactory theory of their origin.

They consist of angular blocks of quartzite, "arranged," according to Pernéty, "as if they had been accumulated carelessly to fill the ravines." The blocks are from two to twenty feet long, and rest "irregularly one upon the other, supported in all positions by the angles and edges of those beneath" (Thomson). At the same time, "they are not thrown together into irregular piles, but are spread out into level sheets or great streams" (Darwin), the surface of one visited by Dr. Coppinger being "tolerably flat," and not indicating "a process of accumulation by flow from either side." The streams vary in width from a few hundred feet to a mile or more. Their depth is unknown, but, according to Darwin, is probably great: though "far down below, under the stones," says Sir Wyville Thomson, "one can hear the stream of water gurgling which

[1] A. J. Pernéty, Histoire d'un Voyage aux Isles Malouires, etc. (nouv. éd., 1770, Paris), vol. ii. pp. 1–6; C. Darwin, Journal of Researches, etc. (1879), pp. 196–199; Sir C. Wyv. Thomson, The Movement of the Soilcap; Nature (Feb. 22, 1877), vol. xv. pp. 359–360; also, Voyage of the 'Challenger,' vol. ii. pp. 245–249; and the Enc. Brit., art. on the Falkland Islands; Dr. R. W. Coppinger, Cruise of the 'Alert' (1885), pp. 32 33.

occupies the axis of the valley; and here and there, where a space between the blocks is unusually large and clear, a quivering reflection is sent back from a stray sunbeam." The inclination of the surface of the stone-rivers is very small, and this is their most remarkable feature. "On the hillsides," says Darwin, "I have seen them sloping at an angle of ten degrees with the horizon, but in some of the level, broad-bottomed valleys, the inclination is only just sufficient to be clearly perceived." The actual movement of the blocks does not seem to have been noticed. "As far as I can ascertain," Dr. Coppinger remarks, "no attempt has ever been made to estimate the rate of movement (if any) of these 'runs,' and there is no evidence whatever of their motion during the present century."

The origin of the blocks themselves has been clearly pointed out by Sir Wyville Thomson. "The beds of quartzite are of very different hardness: some are soft, passing into a crumbling sandstone; while others are so hard as to yield but little to ordinary weathering." Being worn away unequally, the harder bands project, and at last the joint-formed blocks fall over. The difficulty, however, is to account for their present position and arrangement, and, for this purpose, the following theories have been proposed:—

1. The action of earthquakes, hurling the blocks down the slopes, and then levelling them out into continuous sheets (C. Darwin, A. J. Pernéty).

2. The movement of the soilcap enclosing the stones, the soil being afterwards washed away by the streamlets in the valleys (Sir C. Wyv. Thomson).

3. The former movement of "earth-glaciers," which, owing to a change of climate, became desiccated, the earth being afterwards washed away by rain and streams (J. Geikie).[1]

4. The action of frost and snow, the alternate freezing and thawing of rain (Sir J. D. Hooker).[2]

5. The action of glaciers. "I believe it will not be difficult to explain their origin in the light of the glacial theory, and I fancy they may turn out to be ground moraines similar to the 'horse-backs' of Maine" (J. R. L. Agassiz).[3]

6. The alternate expansion and contraction of the blocks under changes of temperature taking place mainly down the slopes, being assisted by gravity in that direction (C. Davison).[4]

It is not my purpose to discuss these suggestions here; but I may remark that, according to Thomson, "ice had no hand whatever in the production of these grand 'moraines' of the Falkland Islands." The second theory has been criticised adversely by Prof. J. Geikie

[1] The Movement of the Soilcap: Nature (March 8, 1877), vol. xv. pp. 397-398.

[2] Himalayan Journals (1854), vol. ii. p. 179 (footnote).

[3] Louis Agassiz: His Life and Correspondence, edited by E. C. Agassiz, vol. ii. pp. 694-695. Extract from a letter to Prof. B. Peirce, dated Feb 20, 1871. It should be noted that Agassiz's intention of visiting the Falkland Islands was never carried out.

[4] Note on the Movement of Scree-material: Quart. Journ. Geol. Soc. (1888) vol. xliv. pp. 232-237.

and Dr. Coppinger with, I believe, conclusive force. With regard to the sixth, though slight movements of this nature must undoubtedly be taking place, they must in this case be unusually small, for the climate of the Falkland Islands is dull and the sky almost continually overcast.[1]

Now, in all of the above-mentioned theories, the transport of the quartzite blocks over considerable distances is taken for granted, and the object of the theories is really to account for this transport over a rough and irregular surface, inclined generally at a very small angle to the horizon. But is it not possible that this assumption is unnecessary; that the blocks, though they have doubtless undergone some movement, still remain in the immediate neighbourhood of the places they occupied before the valleys were formed; that the stone-rivers are, in fact, but an extreme case of the inability of a stream to remove the debris in its course?

On the summits of many of our mountains, we have a phenomenon not unlike the stone-rivers in appearance, and perhaps similar to them in origin. The so-called "blocky structure," so conspicuous, for example, on Scawfell Pike, occurs in many, if not in most, cases where alternate bands of hard and soft rock crop out at the summit. The softer layers, being more easily weathered, are gradually removed by wind and rain; and, in course of time, the joint-formed blocks of the harder projecting bands fall over in various directions, giving rise to that confused, tumultuous appearance, which seems at first sight to suggest the action of an overwhelming force. The blocks remain almost as they fall, for the forces in action on the mountain-summits are insufficient to displace them greatly.

Now, in the Falkland Islands, we have, as we have seen, somewhat similar conditions; bands of hard quartzite separated by seams of soft and crumbling sandstone. When streams began to flow over the primitive surface of the country, they bore away, I imagine, the loosened debris of the softer bands, but the resulting blocks of quartzite were too heavy to be moved by them and hard enough to resist atmospheric disintegration. The streams then flowed between and below the blocks, and continued to remove the softer bands beneath, working their way from side to side of the valleys. The quartzite blocks thus gradually subsided vertically all over the valleys, most along the axis and in the lower regions, least at the sides and in the upper parts, forming on the whole a gently sloping surface,[2] but rough and irregular in its details owing to the different

[1] "The temperature is very equable, the average of the two midsummer months being about 47° Fahr., and that of the two winter months 37° Fahr. The sky is almost constantly overcast, and rain falls, mostly in a drizzle and in frequent showers, on about 250 days in the year. The rainfall is not great, only about 20 inches." Enc. Brit., art. on the Falkland Islands.

[2] It should be noted that the quartzite bands are often much crumpled and distorted, but the surface of the stone-rivers would be fairly smooth in any part, if the total thickness of the quartzite bands formerly above that part were approximately the same all over it. Sir Wyville Thomson states, however, that "the general colouring [of the islands] is dark brownish-green, relieved along the strike of the hills by veins of white quartzite denuded by the wearing away of softer rocks on both sides, and left projecting on the mountain-slopes like dilapidated stone dykes" (Enc. Brit.).

sizes of the blocks and the various directions of their fall. The surface of the stone-rivers might thus be continuous with the slopes of the surrounding country; there would not necessarily, although there might, be bounding cliffs.[1] In the "blocky structure" of mountain-summits, a limit in depth must soon be reached, beyond which wind and frost and rain can have but little effect in weathering and removing the softer rock. But, in the stone-rivers of the Falklands, the process may be carried very much further: as long as streams are able to find their way among the blocks and can remove the sand between them.

This theory seems to me to account satisfactorily for the features of the stone-rivers, so far as they are given in the published narratives. It accounts also for another fact which is not referred to in the theories mentioned above, namely, the proportion of the volume of the quartzite blocks to the volume of the rock that must originally have occupied the valleys. From the slight slope of the surface, and the certainly not small depth, of the stone-rivers, we must infer that this proportion is not inconsiderable. If the formation of the stone-rivers, then, began some time after the commencement of denudation in the islands, not only must the quartzite blocks resulting from previous erosion in some way have been removed, but the valleys must also have greatly increased in width in order to provide the material for the stone-rivers: a large amount of the softer rock must have been carried away: and, therefore, in part, at least, a cause like that suggested in this paper must have been in action. But if we suppose that the formation of the stone-rivers has all along taken place concurrently with the excavation of the valleys, we can, I think, account for the origin of the former without having to call in the aid of any non-existing agencies to explain the transport of the blocks.

IV.—Note on *Rhinobatus bugesiacus*—a Selachian Fish from the Lithographic Stone.

By A. Smith Woodward, F.G.S., F.Z.S.

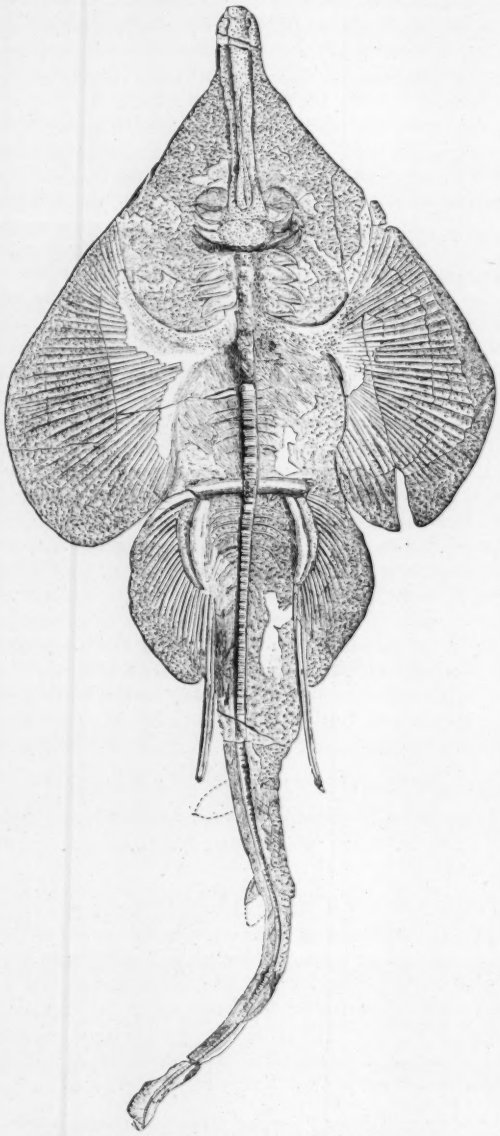
SINCE 1857,[2] the occurrence of a gigantic species of the Selachian family Rhinobatidæ in the Lithographic Stone of Bavaria has been well known, and three fine specimens are exhibited in the Munich Museum. No figure, however, appeared until 1887, when Dr. K. A. von Zittel published[3] the illustration he has kindly allowed to be reproduced here; and the only detailed description is that of Wagner,[4] written about thirty years ago. Quite recently, the British Museum has acquired the counterpart of one of the fossils in the Munich collection—a female individual in a remarkable

[1] "Why," asks Dr. Coppinger, "do they [the stone-rivers] exhibit a margin so sharp and well-defined, yet without the elevated rounded appearance of a river-bank?"

[2] A. Wagner, Gelehrte Anz. bay. Akad. Wiss. vol. xliv. (1857), p. 292.

[3] Handb. Palæont. vol. iii. p. 103, fig. 117.

[4] Abh. k. bay. Akad. Wiss. Math.-phys. Cl. vol. ix. (1861), p. 313.



Rhinobatus Bugesiacus (Thiollière? sp.).
Lithographic stone, Eichstatt, Bavaria (after Zittel).
(One-twelfth nat. size.)

state of preservation; and this is now exhibited in the form of a slab upon the west wall of the Gallery of Fossil Fishes.

The specimen in question is complete in all important respects, only the proximal portion of the left pectoral fin and non-essential parts of the median fins being wanting; but the vertebral column, except towards the extremity of the tail, is shown as fragments or merely in impression, and the jaws are unfortunately buried in the matrix. The fish is exposed from the dorsal aspect, measuring 1·50 m. (about 5 ft.) in total length; and in general form it agrees with the male individual represented in the accompanying figure. The snout is remarkably produced, and on the outer side of each nasal capsule is a long slender forwardly-directed cartilage, evidently to be regarded as prepalatine. The basal pterygia of the right pectoral fin are more clearly shown than those of the Munich fossil, as here figured, the mesopterygium being large and broad, the propterygium long, slender, and segmented distally, and the metapterygium somewhat stouter than the latter; the large, very broad cartilaginous fin-rays are also all distinct. The dorsal fins are relatively larger than indicated by the outlines in the figure; and the caudal fin has a slightly greater expanse, though this may be due to difference in crushing during fossilization. Coarse rounded shagreen-granules cover the dorsal aspect of the cranium, the pectoral arch, and the longitudinal middle line of the back; but there are no large tubercles or spinous defences.

So long ago as 1836, Count Münster[1] briefly noticed the caudal extremity of a large Selachian from the Lithographic Stone of Kelheim under the name of *Aellopos elongatus*; and in 1843, Agassiz[2] recorded the occurrence of a very large pectoral fin with the provisional name of *Euryarthra Muensterii*. Both these fossils probably pertain to the fish now under discussion, as already suggested by v. Zittel, and, to a certain extent, also by Wagner; but they were not sufficiently described for recognition before 1854, when Thiollière[3] gave detailed notes and figures of specimens from the Lithographic Stone of Cirin, Ain, France, identical in every respect, except size, with the Bavarian species. The name proposed by Thiollière—*Spathobatis Bugesiacus*—is thus applicable to this species; and as there is no significant difference between "*Spathobatis*" and the recent *Rhinobatus*, we prefer to regard the former generic name merely as a synonym of the latter.

When studying the Bavarian "*Spathobatis*," Wagner himself distinctly perceived its identity with the French species described by Thiollière; but owing to the fact, that the former attained twice the size of the latter, he considered a distinct specific name justifiable, and suggested that of *S. mirabilis*. According to modern ideas of nomenclature, however, this name must become a synonym; and an examination of the type-specimen of *S. morinicus*, Sauvage,[4] from

[1] Neues Jahrb. 1836, p. 581.
[2] Rech. Poiss. Foss. vol. iii. p. 382.
[3] Poiss. Foss. Bugey, pt. i. p. 7, pls. i. ii.
[4] Bull. Soc. Académique Boulogne-sur-Mer, 1873, p. 94.

the Portlandian of the Boulonnais, has convinced the present writer that the last-mentioned name must also share the same fate.

Rhinobatus Bugesiacus thus occurs in the Lower Kimmeridgian of Bavaria and S.E. France and in the Lower Portlandian of N.E. France: in the first and last localities it attains its maximum dimensions, while in the second it is comparatively dwarfed. The same species may also perhaps be met with in the English Kimmeridgian, but as only detached vertebræ have hitherto been discovered,[1] it is at present impossible to arrive at a specific determination.

Woodwardian Museum Notes.

V.—On "Eyes" of Pyrites and other Minerals in Slate.

By Alfred Harker, M.A., F.G.S.

AMONG instances of the bodily deformation of rocks by lateral pressure, the case of the *phyllade aimantifère* of Monthermé is well known. By its strong cleavage this rock gives evidence of considerable lateral compression. Professor Renard[2] has shown that prior to this compression the magnetite crystals already existed in the rock, and were surrounded by a coating of chlorite. The crystals yielded to the pressure much less readily than their matrix, and the latter, having already a firm consistence, became separated from the crystals, carrying the chlorite with it, and was displaced along the planes which are now cleavage-planes, that is, in a direction at right angles to that of the pressure.

My object is to show that similar phenomena are not uncommon among cleaved rocks in our own country. Some years ago I obtained from the Penrhyn quarry a specimen of slate with cubes of pyrites, in which the displacement of the matrix around the imbedded crystals is well exhibited. As in the French *phyllade*, the vacant spaces left have been subsequently filled by infiltered quartz, which grew roughly perpendicular to the faces of the crystals. The arrangement is represented in figure 1 (p. 397). As the "eyes" are from half an inch to an inch in length, the pyrites, quartz, and chloritic mineral can be easily distinguished with the naked eye, while a thin section makes a pretty object under the microscope (No. 501). In the *phyllade aimantifère* the magnetite crystals are only 0·2 to 0·8 mm. in length (No. 502). M. Reusch[3] has noticed a precisely similar disposition of quartz and chlorite around dodecahedra of pyrites in a schistose diabase dyke: here too the crystals appear to be only about one-hundredth of an inch in diameter.

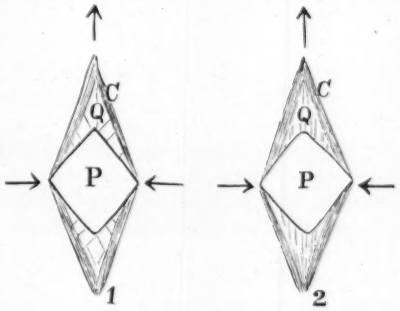
The phenomenon is probably one of wide occurrence. It is seen in sericitic slates at Blaenau Ffestiniog and at other places in North and South Wales; also in the very pyritiferous slates of Ballachulish near Oban. The "eyes" are always flattened parallel to

[1] Catal. Foss. Fishes, Brit. Mus. pt. 1, p. 83.

[2] Bull. Mus. Roy. Hist. Nat. Belg. vol. ii. p. 134, and plate vi. 1883. See also Gosselet's "L'Ardenne," p. 61 and fig. 17, 1888.

[3] Bömmelöen og Karmöen, pp. 69, 70, 1888.

the cleavage-planes and drawn out along the line of cleavage-dip (*longrain* of the French). It indicates that in those cases the pyrites is of very early origin, and that it became coated at an early stage with a chloritic envelope; further, that the rock became thoroughly compacted before it was subjected to the lateral thrust, so that in yielding it was able to leave vacant spaces, which were filled at a later date by crystalline quartz. This last point is proved by the manner in which the quartz has been formed with its crystals perpendicular to the faces of the pyrites. There are, however, other cases in which the quartz has a fibrous structure, the fibres being set parallel to the *longrain*, that is, to the direction of movement, as diagrammatically shown in fig. 2. This is presum-



Sections at right-angles to the cleavage-planes. P = pyrites; Q = quartz; C = chloritic mineral.

ably due to the quartz having been deposited concurrently with the process of deformation, so that no vacant space was actually formed. The examples cited by Loretz[1] from the Thuringerwald must be referred to this kind of action. In these the pyrites has been subsequently converted into limonite.

Another variety of "eye" is found in the Llandeilo slates of Whitesand Bay near St. David's. Here the whole external surface of the "eyes," which are about an inch and a half to two inches long, has a strongly fibrous, slickensided aspect. On making a section, it is seen that the pyrites cubes have their angles and quoins rounded off, and little fragments of pyrites are detached and enveloped in the quartz which occupies the corners of the "eyes."

It should be noted that these lenticular or eye-shaped masses are essentially characteristic of *discontinuous* sliding movement, in which actual disruption has taken place between substances capable of different degrees of yielding, such as the hard pyrites and the less hard rock surrounding it. The same rocks often exhibit the ellipsoidal green spots (distorted spheres) first noticed by Dr. Sorby, which indicate *continuous* deformation without abrupt slipping.

[1] Jahrb. d. königl. preuss. geolog. Landes. for 1881, pp. 283–289.

VI.—On *Phillipsastræa*, d'Orb., with Especial Reference to *Phillipsastræa radiata*, S.-Woodward sp., and *Phillipsastræa tuberosa*, M'Coy, sp.

By Rudolph Schäfer, Ph.D.

(PLATE XII.)

THE genera *Phillipsastræa* and *Smithia* have long been a source of trouble to palæontologists, and since the establishment of the latter genus in 1851, it has been very doubtful in which of the two genera certain species of Corals should be placed. The more extended our acquaintance with the species belonging to both genera became, the more probable it seemed that the distinctions between them were in reality unimportant and insufficient to justify a division into two different genera. It was in fact proposed by Kunth as early as 1870 that both genera should be united under the earlier name *Phillipsastræa*. It has been stated that *Phillipsastræa* possesses a columella, while *Smithia* has none; upon the truth of this statement the retention of the two genera depends. Kunth has denied the existence of such a difference. Nevertheless both genera are still retained. From a careful study of the specimens in the British Museum (Natural History) and in the Woodwardian Museum at Cambridge, I have come to the conclusion that Kunth's opinion is well founded; and in the following remarks I shall further attempt to show that certain species which are still sometimes described as having a true columella do not really possess one.

I am indebted to Dr. Henry Woodward, F.R.S., the Keeper of the Geological Department in the British Museum (Natural History), for granting me facilities for the study of the specimens of *Phillipsastræa* and *Smithia* under his care, and also for the privilege of having sections made from them, without which their characters could not have been determined. I also owe Professor T. McKenny Hughes my best thanks for his kindness in allowing me to examine the specimens in the Woodwardian Museum at Cambridge.

Before giving a description of the specimens in question, a few short notes on the history of both genera might not be without interest.

History of the genera.—In the year 1849 d'Orbigny established the genus *Phillipsastræa*, of which he gave the following diagnosis[1]: "*Phillipsastræa*, d'Orb., 1847.[2] Ce sont des *Siderastrea*, dont la columelle, au lieu d'être styliform saillante, est large et divisée en cloisons rayonnantes, comme chez les *Columnastræa*." He gives two species:—*Phillipsastræa parallela*, d'Orb., 1847=*Astrea parallela*, F. A. Roemer, Verst. d. Harzgeb. 1843, p. 5, pl. 3, fig. 1.—*Phillipsastræa Hennahii*, d'Orb. 1847=*Astræa Hennahii*, Phillips, 1841. Pal. foss. pl. 6, fig. 16.

[1] A. d'Orbigny, Prodrome de Paléontologie, etc. vol. i. p. 107, Paris, 1849.

[2] This date is not correct, because though d'Orbigny's manuscript was ready for publication in the year 1847, as he states in the preface, yet the book was not published until 1849.

In the year 1850 Messrs. Edwards and Haime[1] mentioned the genus *Phillipsastræa*; the genus *Smithia* was not established at that date. Their diagnosis of *Phillipsastræa* contains the words: "The centre of the tabulæ presenting a columellarian tubercle." As the type species they mention *Phillipsastræa Hennahii*, Lonsd. (=*Astræa Hennahii*, Lonsd., in Geol. Trans., 2nd ser. vol. v. pl. 58, fig. 3). This is of importance, as in the following year this very species became the type of the genus *Smithia*.

In the year 1851 Messrs. Edwards and Haime established the genus *Smithia*:[2] "*Smithia*. Polypier ayant la même structure que les *Acervularia*, mais manquant de murailles extérieures distinctes et présentant des rayons septo-costaux plus ou moins confluents," and (*loc. cit.* p. 421): "Pas de columelle." Type species: *Smithia Hennahii* (=*Astræa Hennahii*, Lonsd.), the same species which in 1851 was the type of *Phillipsastræa*. The following species of *Smithia* are given: *Smithia Hennahii*, Lonsd., *Smithia Pengellyi*, E. & H., *Smithia Bolonieusis*, E. & H., and *Smithia Bowerbankii*, E. & H.

In the diagnosis of the genus *Phillipsastræa* we read (Mon. des Polyp. Foss. p. 173): "*Phillipsastræa*. Polypier présentant la même structure que les *Smithia*, mais ayant une columelle styliforme," and (*loc. cit.* p. 447): "Les Phillipsastrées diffèrent des Smithies par la présence de leur columelle." Type species: *Phillipsastræa radiata*, S. Woodw. The following additional species are mentioned: *Phillipsastræa Verneuili*, E. & H., and *Phillipsastræa tuberosa*, M'Coy.

In the diagnosis of the type species *Phillipsastræa radiata* (*loc. cit.* p. 448) we read: "columelle mince et comprimée, en général peu distincte;" the figure (Brit. Foss. Cor. tab. 37, fig. 2) shows no columella. In the description of *Phillipsastræa tuberosa*, (*loc. cit.* p. 449) Messrs. Edwards and Haime do not mention any columella, neither does M'Coy.[3] Further, the figures given by M'Coy[4] do not present, either in the transverse section or on the surface, any indication of a columella. In the diagnosis of *Phillipsastræa Verneuili* (*loc. cit.* p. 448) Messrs. Edwards and Haime say: "columelle saillante"; the figure (Mon. des Polyp. Foss. tab. x. fig. 5) shows the same clearly, but only on the surface, since a transverse section is not given.

Kunth[5] has already explained all that has been mentioned so far. He has also given (*loc. cit.* p. 30, and tab. i. fig. 4) an exact description of *Phillipsastræa Hennahii*, Lonsd. (= *Smithia*

[1] H. Milne Edwards and J. Haime, A Monograph of the British Fossil Corals, part i. Introduction, p. lxx. Palæontographical Society, vol. iii. London, 1850.

[2] H. Milne Edwards et J. Haime, Monographie des Polypiers Fossils des Terrains Paléozoïques, etc., Archives du Muséum d'Histoire Naturelle, tome v. p. 171, Paris, 1851.

[3] F. M'Coy, On some Genera and Species of Palæozoic Corals and Foraminifera, Ann. Mag. Nat. Hist. 2nd ser. vol. iii. p. 124, London, 1849.

[4] A Synopsis of the Classification of the British Palæozoic Rocks, by A. Sedgwick; with a Systematic Description of the British Palæozoic Fossils in the Geological Museum of the University, Cambridge, by F. M'Coy, pl. 3*b*, fig. 8, 8*a*.

[5] A. Kunth, Beiträge zur Kenntniss fossiler Korallen, Zeitschrift der Deutschen geologischen Gesellschaft, vol. xxii. p. 30, Berlin, 1870.

Hennahii), which contains many valuable remarks, especially in reference to the microscopical structure. In this species the calyx shows a false columella ("columellarian tubercle," as he himself adds in parenthesis), but the sections show no columella. Kunth, therefore, doubts the correctness of making the presence of a columella a distinction between the genera *Phillipsastræa* and *Smithia*; moreover, according to Messrs. Edwards and Haime, *Smithia* also has on the tabulæ a columellarian tubercle, and in *Smithia Hennahii* and *Smithia Bowerbanki* they mention "lobes paliformes," such as might produce a similar structure in the calyx to that shown in the figure of *Phillipsastræa Verneuili*.

Kunth, therefore, arrived at the following conclusion: There is no generic distinction between *Phillipsastræa* and *Smithia* so far as the presence or absence of a columella is concerned; a columella might perhaps be present in *Phillipsastræa Verneuili*, but in this case it would have to be shown in a section. Consequently the four species separated under the name *Smithia* by Messrs. Edwards and Haime must be referred back to *Phillipsastræa* and the name *Smithia* must be abandoned.

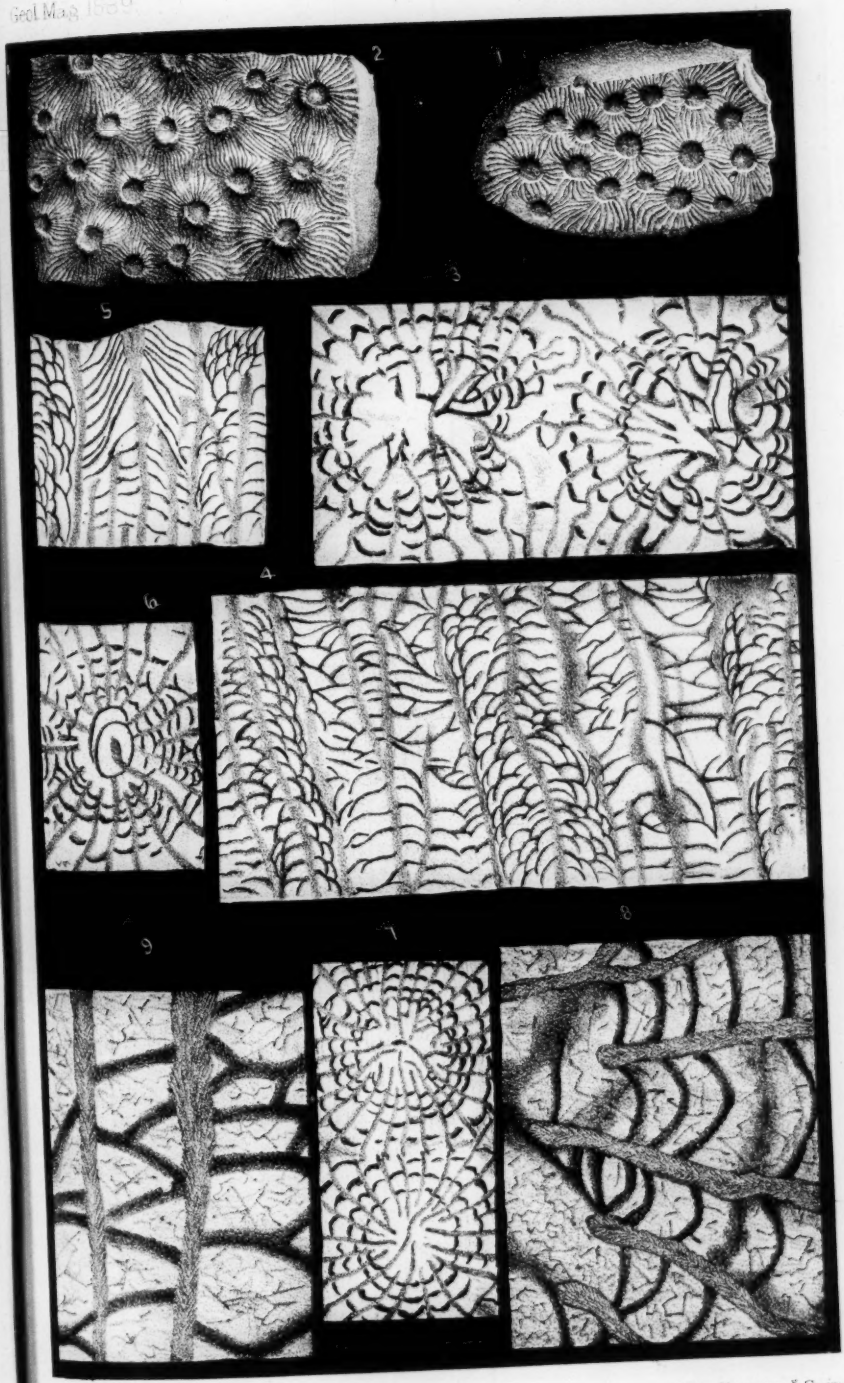
In the year 1876 Rominger[1] gave a description of *Phillipsastræa Verneuili*, in which he says: "The centre of the calyx bottom is raised into a columellar knot, and in vertical sections of calcified specimens a central string of greater density can be observed, but it is not a solid axal column; in some species no indication of a columella is perceptible." Thus it was clearly shown in a section, that the only species about which doubt still existed—*Phillipsastræa Verneuili* — did not possess a columella. Therefore, Rominger also united the genus *Smithia* with *Phillipsastræa*. In the generic diagnosis of *Phillipsastræa* he says (*loc. cit.* p. 128): "The longer lamellæ unite in the centre and form a pseudo-columellar, nodular protuberance, but do not connect into a continuous vertical axis."

Since this time, therefore, Lindström, C. Ferd. Römer, v. Zittel, and others have united the genera.

Mr. James Thomson,[2] however, who in 1883 described certain species of *Phillipsastræa* from the Carboniferous rocks of Scotland, remarks that the species in question possesses a columella. Of *Phillipsastræa radiata* he says (*loc. cit.* p. 395): "there is a central compressed prominent columella in some coralets," and further, "in a longitudinal section the tabula [*sic*] are irregular; some are rectangular, but the great proportion are bent upwards and meet in the centre and form a more or less discontinuous columella." His figures, however (*loc. cit.* pl. iv. fig. 1, 1a, 1b), show no columella, only in one single corallite (pl. iv. fig. 1) four septa are seen to meet. Neither does the longitudinal section show any columella. Of

[1] C. Rominger, Geological Survey of Michigan, Lower Peninsula, vol. iii.; part ii. Palæontology, Corals, p. 128, pl. 23, fig. 2, New York, 1876.

[2] J. Thomson, On the Development and Generic Relations of the Corals of the Carboniferous System of Scotland, Proc. Phil. Soc. Glasgow, vol. xiv. p. 394, Glasgow, 1883.



Benjeau & Highley lith

West, Newman & Co imp

Phillipsastraea radiata S.Woodw. sp.

Phillipsastræa tuberosa he says (*loc. cit.* p. 396) "the corallum is mammillated, and there is a stout laterally-pressed columella."

It is evident that, if Mr. Thomson were correct in stating that *Phillipsastræa radiata* and *Phillipsastræa tuberosa* really possessed a columella, then the union of *Phillipsastræa* and *Smithia*, as proposed by Kunth and accepted by subsequent writers, would be incorrect; on the contrary, both genera would have to be maintained in the sense in which they were proposed by Messrs. Edwards and Haime.

It therefore appeared to me desirable to re-examine the original specimens of M'Coy and of Messrs. Edwards and Haime, which are contained in the Woodwardian Museum at Cambridge, as also the specimens in the British Museum (Nat. Hist.), to ascertain whether they possessed a columella or no. Below I give a short description of the specimens, together with the results of the observations I was able to make.

PHILLIPSASTRÆA RADIATA, S. Woodw. sp.

(*Tubipora radiata*, S. Woodw., Syn. Table of Brit. Organic Remains, p. 5, 1830).

Spec. Char.—Corallum massive, composite, forming irregular broad astræiform masses. Distance from centre to centre of the calices from 5mm. to 12mm. Diameter of the calicular axial fossa from 2mm. to 3mm. The circumference of the calicular fossa raised in a slightly prominent rim. The inclination of the inner surface of this calicular fossa almost perpendicular. Depth of the calicular fossa about 1mm. Septa thin, 22–30, and confluent with those of the neighbouring calices. Septa alternately longer and shorter; of the longer septa two or more opposite ones meet and thus form in the calicular fossa a transverse ridge, which sometimes is joined by other septa. The shorter septa reach only a very short way into the calicular fossa. Vesicular tissue is plentifully developed between the septa. It consists of hollow, semicylindrical vesicles, the concave side downwards, axis of the semicylinders perpendicular to the septa. In close proximity to the calicular fossa the vesicles are somewhat smaller, more closely set, and the concave side is here turned downwards and outwards. In the inner part of the corallite tabulæ are developed; these are mostly horizontal, still they occasionally bend upwards in the middle and thus assume the form of an obtuse cone with its apex uppermost.

Observations and Remarks.—It is known that this species was proposed by Messrs. Edwards and Haime for certain Corals, described by M'Coy partly as *Sarcinula placenta*, partly as *Sarcinula Phillipsi*. The specimens in the Cambridge Museum were the type specimens of Edwards and Haime, these being also the original specimens of M'Coy. During my visit to Cambridge I had the opportunity of studying them. They agree in so many points that Edwards and Haime appear to have had very good ground for classing them as one species. The specimen described and figured by M'Coy as *Sarcinula placenta* shows somewhat smaller dimensions than that which he describes as *Sarcinula Phillipsi*. Moreover, when M'Coy states that in *Sarcinula placenta* the tabulæ are more horizontal,

whilst those in *Sarcinula Phillipsi* are cone-shaped and bent upwards, he is perfectly correct. To this question I shall recur later on, but I would here remark that no distinction of species can be based on this difference of tabulæ, since the two species are connected by individuals showing numerous intermediate gradations.

Arrangement of the septa.—As already mentioned two or more opposite septa in each calyx meet and form a kind of ridge, which other septa join. In this way are produced configurations in the calicular fossa, which, it must be admitted, sometimes closely resemble a columella. This resemblance however is merely superficial; closer observation with the lens shows that the septa only meet. On p. 403, Figs. 1–3 I give enlarged figures of the middle parts of some corallites from one of the type specimens of *Phillipsastræa radiata*, E. & H. (type of *Sarcinula Phillipsi*, M'Coy), which I was able to prepare at the Museum in Cambridge. The type specimen of M'Coy's *Sarcinula placenta* does not show on the surface that septa join inside the calicular fossa; but this I believe is only owing to the imperfect state of preservation. There are however in the British Museum (Nat. Hist.), as also in the Cambridge Museum, other specimens, some of which do actually show configurations which appear to be columellæ. But this is not always the case, as I have already pointed out, and neither the figure given by Phillips,[1] nor that given by M'Coy,[2] to which Edwards and Haime refer in their description of the species, nor that which they themselves give,[3] shows a columella. Thomson's fig. 1, pl. iv. shows only in one single corallite a junction of four septa. The question, however, whether *Phillipsastræa radiata* has or has not a true columella can only be decided by sections. The only three sections, which have hitherto been figured[4] show nothing conclusive. New sections were prepared. It was impossible to make sections of the typical specimens in the Museum at Cambridge without destroying those parts figured by M'Coy. Accordingly, sections of unfigured specimens in the British Museum and in my own collection were prepared. The said specimens exactly corresponded in all essential characteristics with the type specimens. In consequence of this I was able to examine four horizontal and six vertical sections of four different specimens which were found in the Carboniferous Limestone at Haford-y-Calch near Corwen, North Wales, and in the Avon section, near Bristol.

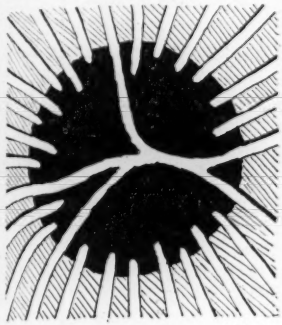
In horizontal section the calices show the same phenomenon as is sometimes observed, although not so clearly, on the surface of the corallum. I was not able to identify in the specimens before me that bilaterally-symmetrical arrangement of the septa, which according to Kunth's researches forms so distinctive a characteristic of

[1] J. Phillips, Palæozoic Fossils of Cornwall, Devon and West Somerset, pl. vii. fig. 15D, London, 1841.

[2] M'Coy, Brit. Pal. Foss. pl. iii.B, figs. 9, 9*a*, 9*b*.

[3] Milne Edwards and J. Haime, Brit. Foss. Cor. pl. 37, fig. 2.

[4] M'Coy, Brit. Pal. Foss. pl. 3B, figs. 9*a*, 9*b*.—M. Edwards and J. Haime, Brit. Foss. Cor. pl. 37, fig. 2*a*.—J. Thomson, *loc. cit.* pl. iv. figs. 1, 1*a*.



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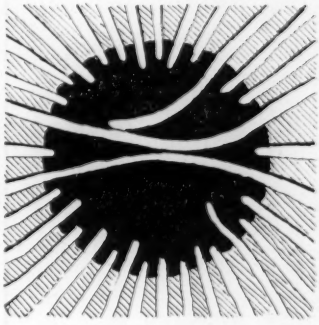

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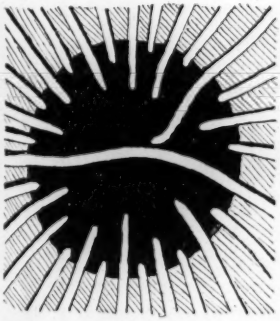

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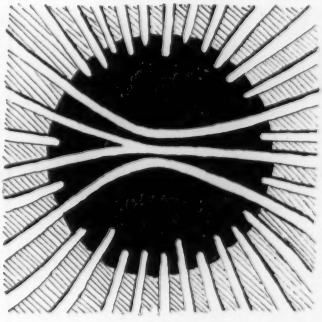

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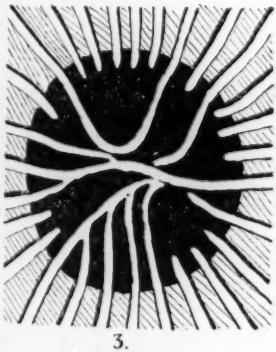

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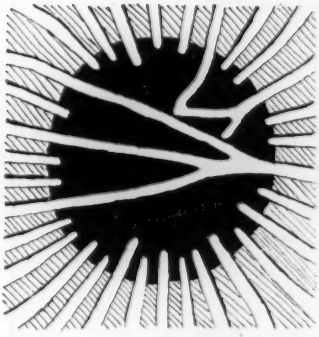

6.

FIGS. 1, 2, 3. Outline of calices of type-specimen of *Phillipsastræa radiata*, S. Woodw. sp. (= *Sarcinula Phillipsi*, McCoy).

FIGS. 4, 5, 6. Type of *Phillipsastræa tuberosa*, McCoy (= *Sarcinula tuberosa*, McCoy).

the *Tetracorallia*. The reason of this may be that the arrangement above mentioned is shown usually only in young Corals. Kunth[1] himself could not distinguish the bilaterally-symmetrical arrangement of the septa in the genus *Phillipsastræa*, but could distinguish it clearly enough in the closely-related genus *Acervularia*. Under these circumstances I must refrain from indulging in any speculation as to the position of the "*Hauptseptum*" the "*Gegenseptum*" and the "*Nebensepta*," and confine myself solely to giving a description of those relations which I really observed.

All the corallites in the sections show two kinds of septa; when regularly and normally developed, 12 longer septa and 12 shorter alternating seemed to be the number. Such regularity in the development I could not, however, observe in every case; in most cases more than 24 septa were present, and here and there two of the shorter septa came between two of the longer, and often some of the longer septa were shortened and could hardly be distinguished from the shorter. The sections (see Pl. XII. Figs. 3–7) show clearly that in most cases two or more opposite septa unite and form a continuous line, which traverses the whole corallite. In the central part this line is often somewhat thicker; it is in some cases joined by others of the longer septa. No columella is seen in any of the corallites, either in the horizontal or in the vertical sections.

The vertical section of two neighbouring corallites of the best preserved specimen, Pl. XII. Fig. 4, cuts exactly the vertical axis of the latter, only the upper part of the section (owing to an accident of growth) is slightly excentric, that is to say, intersects the imaginary axis of the corallite at a very acute angle. Accordingly the upper part of the figure shows the section of two neighbouring septa, but further down, where the section runs through the central axis, it intersects the point where two neighbouring septa join, and the lower part of the figure shows but one septum line; here these two septa are joined together. The four other vertical sections which I examined agree with this in every particular of importance—a columella is nowhere to be observed.

Wall.—On the upper surface of the coral no wall can be perceived, but the distal ends of the septa of the neighbouring corallites appear to run into one another. Nevertheless some indication of a wall may be perceived here and there in that the septa in some places are not altogether confluent, but the line of apparent junction is broken, and so suggests the place where a wall might be. Neither is any wall perceptible in the horizontal sections of *Phillipsastræa radiata*. When more highly magnified however, one often sees that the septa of neighbouring corallites are not really confluent, but that they overlap each other and are separated by a small space. Sometimes indeed, but very rarely, the septa do run together in a continuous line.

It is worthy of notice that a so-called interior wall unquestionably does not exist. It was formerly generally supposed that in all

[1] A. Kunth, Das Wachsthumsgesetz der Zoantharia rugosa, etc., Zeitschrift der Deutschen geologischen Gesellschaft, vol. xxi. p. 659, Berlin, 1869.

species of *Phillipsastræa* the proper wall was wanting, but that an interior mural investment existed, the presence of which was looked upon as a generic character. This view, however, certainly does not hold good in the case of those species examined by me. Only in very rare cases, in single corallites, could I perceive near the outer part of the central cavity anything that would suggest the rudiments of a wall between the septa. These rudiments show in horizontal sections the same arrangement as the vesicles, but differ from the latter in that they have the same structure as the septa. These rudiments of an interior wall are only of very limited extent, they comprise at the most only one-eighth of the circumference of the calicular fossa, and are besides so seldom met with, that they appear to be unimportant for purposes of classification, and I consider them rather as abnormal structure. Pl. XII. Fig. 7 shows a corallite in which such rudiments occur. In the same way Schlüter and Barrois have disproved the existence of an interior wall in certain species of *Acervularia*.

Endothecal sclerenchyma.—The endothecal sclerenchyma which fills up the interseptal loculi consists of semicylindrical vesicles with their concave side turned downwards, which lie above one another in alternating rows. This arrangement is substantially the same as that of *Phillipsastræa Hennahii*, the internal structure of which has been described by Kunth. To illustrate the structure he has very aptly likened the arrangement of the vesicular tissue to that of "semicircular drain-tiles." The figure which he gives (*loc. cit.* p. 33) will also facilitate the comprehension of the structure of *Phillipsastræa radiata*. In the inner part of the calyx, where the vesicles surround the central cavity, they are closer and more perpendicularly arranged, whilst in the outer parts of the calyx the vesicles are coarser and flatter (Pl. XII. Fig. 4). It is nevertheless difficult to see whether the different forms of vesicles really represent a different structure, or whether it is merely due to the difference of angle at which the section cuts the axis of the semicylinder. A section at right angles to this axis would give the first appearance, while the second appearance would be produced by a section more nearly parallel to the axis.

The vesicles reach as far as the septa, but do not extend through or into them, also their minute structure is quite different from that of the septa.

Tabulæ.—In the middle part of each corallite tabulæ exist. They extend outwards as far as the closer and more perpendicularly arranged vesicles, and continue through the central cavity at equal distances. The distances between the single tabulæ are a little greater than between the vesicles in the endothecal tissue. They are either level, or are slightly bent upwards in the middle, and so take the form of an obtuse hollow cone, with its apex uppermost.

Both kinds of tabulæ are connected by gradations, and occasionally both horizontal and cone-shaped tabulæ may be observed in the same specimen. If a horizontal section is made of a cone-shaped tabula, we see only a circle inside the central cavity as on Pl. XII. Fig. 6.

The space which in the living animal would exist between the tabulæ and the vesicles in the interseptal loculi, becomes filled up by a stony matrix in the process of fossilization. In weathering this stony mass offers less resistance than either septa, tabulæ or endothecal sclerenchyma. Accordingly the appearance which the corallum presents after the surface has been weathered depends largely on the original structures.

Where the tabulæ are conical and bent upwards, the weathered surface appears mammillated, whilst the surface is almost flat where the tabulæ are more horizontal. Since gradations exist between the different kinds of tabulæ, we must expect to find on the surface of weathered specimens all varieties between smooth and mammillated calyces. It seems to me impossible to consider the specimens with a mammillated calyx as of a distinct species from those with a flat calyx. On Pl. XII. Figs. 1 and 2 I give an illustration of two specimens, of which one, Fig. 1, shows a smooth surface, whilst the other, Fig. 2, appears somewhat mammillated; but in other parts of the same specimen the surface of the calyces appears smoother. The bearing of this fact on the specific distinction between *Phillipsastræa tuberosa* and *Phillipsastræa radiata* is obvious.

Minute structure of the septa, the vesicles, and the tabulæ.—The state of preservation of the specimens examined by me was very favourable, and allowed me also to study the minuter details in the sections.

The septa are formed of bundles of calcite fibres, which lie on either side of the median plane of the septum. From this starting point on this plane each fibre passes upwards and outwards in the direction of the proximal end of the septum. Thus a feather-like structure is brought about in the sections, which reminds one of that which Pratz[1] has described and figured for *Thamnastræa*. Pl. XII. Fig. 8, shows this structure in horizontal section, whilst in Pl. XII. Fig. 9, may be seen the same in vertical section. Examined by polarized light, with crossed Nicols, the single calcite fibre shows straight extinction, that is to say, becomes dark when by the turning of the stage the fibre is parallel to the principal section of each Nicol. Hence it arises that each single calcite fibre is a crystallographic individual. The vesicles and tabulæ differ from the septa, but resemble one another in histological structure. This proves that in the living animal the vesicles and tabulæ were produced in the same manner. When viewed with a higher power they do not become transparent, but always remain opaque. Under a still higher power they occasionally appear separated into heaps of fine granules.

The difference of structure between the septa on the one hand, and the vesicles and tabulæ on the other, arises chiefly through their having originated in a different manner in the living animal. If we consider that as the living animal grows upwards it secretes the

[1] E. Pratz, Ueber die verwandtschaftlichen Beziehungen einiger Korallengattungen mit hauptsächlichster Berücksichtigung ihrer Septalstructur. Palæontographica, vol. xxix. p. 81, pl. xiv. fig. 12, Cassel, 1882–1883.

tabulæ and vesicles beneath itself, we shall see that the latter structure must have the same histological origin as the sclerobasis; that is to say, it is the secretion of that part of the ectoderm which invested the deepest parts of the calicular fossa. In the tabulæ and vesicles then the calcification could only take place from below upwards; the septa, on the contrary, were arched over by the ectoderm, and the calcification could continue both upwards and on either side.

Phillipsastræa tuberosa, M'Coy sp.

(*Sarcinula tuberosa*, M'Coy, Ann. Mag. Nat. Hist. 2nd series, vol. iii. p. 124, 1849).

Spec. Char.—Corallum massive, composite, astræiform. The upper surface covered with irregular tuberose projections, separated by flat or concave spaces. Corallites very irregularly arranged. Distance from centre to centre of the calices 5 mm. to 15 mm. Circumference of calicular fossa prominent; consequently the upper surface looks mammillated. Diameter of calicular fossa $2\frac{1}{2}$ mm. to 4 mm. Depth of calicular fossa 1 mm. Septa very thin, about 32, confluent with those of the neighbouring calices. Septa alternately longer and shorter, the shorter ones reaching only a very short way into the calicular fossa. In many corallites some of the longer opposite septa join, and thus occasionally produce the appearance of a stout, laterally compressed columella (false columella). Vesicular tissue, closely resembling that of *Phillipsastræa radiata*, is developed between the septa. The tabulæ are cone-shaped, and bent upwards in the middle part.

Observations and Remarks.—This species was founded by M'Coy,[1] for a specimen from the Carboniferous Limestone of Derbyshire, which is now in the Woodwardian Museum, Cambridge. He called it *Sarcinula tuberosa*. Messrs. Edwards and Haime afterwards accepted the species as *Phillipsastræa tuberosa*,[2] though not without some hesitation. They write thus (*loc. cit.*): "Cette espèce ne diffère peut-être pas de la *Ph. radiata*." I had an opportunity of studying the original specimen of M'Coy and Edwards and Haime in the Museum at Cambridge. A comparison of this specimen with the type specimen of *Sarcinula placenta*, M'Coy, certainly discloses such striking differences that a separation into two species appears to be well founded. Less noticeable is the difference between the type-specimens of *Sarcinula Phillipsi*, M'Coy, and *Sarcinula tuberosa*, M'Coy. Besides the original specimens of *Ph. radiata*, there are others both in the Woodwardian Museum and in the British Museum, the surface of which is more or less mammillated, so that, although they belong to *Ph. radiata*, they nearly approach to *Ph. tuberosa*. Messrs. Edwards and Haime appear, therefore, to be justified in expressing a doubt as to the validity of *Ph. tuberosa*. Further it is remarkable that amongst all the numerous specimens which I

[1] M'Coy, On some New Genera and Species of Palæozoic Corals and Foraminifera, Ann. Mag. Nat. Hist. 2nd ser. vol. iii. p. 124, London, 1849.

[2] Milne Edwards and J. Haime, Pol. Foss. des Terr. Paléoz. p. 449, Paris, 1851.

examined in the Museum at Cambridge, in the British Museum and in my private collection, there was not a single one which could be classed as *Phillipsastræa tuberosa*, except the single specimen which formed the type of M'Coy's *Sarcinula tuberosa*.

This specimen is not very well preserved. It is much weathered and traversed by several fissures, which have been again closed by infiltration. Since it had been figured in Brit. Palæoz. Fossils, pl. 3*b*, fig. 8 and 8*a*, the preparation of sections was impossible without destroying some of the figured parts. I was therefore obliged to confine myself to the study of those parts which may be seen on the surface. The arrangement of the septa is exactly the same as in *Ph. radiata*. Here also the opposite septa occasionally join and form a continuous line through the calicular fossa. Other of the longer septa join them also. On p. 403, Fig. 4–6, are diagrams of corallites prepared from the type specimen at Cambridge.

M'Coy's figure is not quite exact and does not faithfully represent the course of the tabulæ. The arrangement of the vesicles is essentially the same as in *Ph. radiata*, the tabulæ are cone-shaped, or bent upwards in the middle part of the central cavity. Altogether they present the same appearance which is occasionally presented by *Ph. radiata*. If *Ph. tuberosa* be really a separate species of *Ph. radiata*, the differences are certainly extremely small. But unless a further specimen be found, which may undoubtedly be classed with the type-specimen I think we should be right in referring it to *Ph. radiata* and looking upon it only as a variety, or as the extreme stage in the development of mammillated corallites, the tabulæ of which are cone-shaped and bent upwards.

Concluding Remarks.—I have endeavoured to prove in my investigations that the two species *Phillipsastræa radiata* and *Phillipsastræa tuberosa*, in which a columella was supposed to be present, do not possess one. Consequently there is no important difference between the genera *Smithia* and *Phillipsastræa*, and we must, according to Kunth, unite the genus *Smithia* with the prior genus *Phillipsastræa*.

Lastly, some general remarks on the relationship of the genus *Phillipsastræa*. The genus *Phillipsastræa* is on the one hand closely related to *Acervularia*. Frech[1] declared both genera to be so closely related and the differences so slight that he proposed to unite them under the name *Phillipsastræa*; this proposition, however, has not been accepted by Steinmann, Neumayr and Barrois in their most recent publications. On the other hand, frequent mention is made of relationship between *Phillipsastræa* and *Heliophyllum*. This relationship is assumed chiefly from the fact that in certain species of *Phillipsastræa* the septa are crossed by conspicuous cross-bars or denticulations, just as in *Heliophyllum*. The same phenomenon has also been observed in different species of *Acervularia*. Our knowledge of the internal structure of the different species of *Phillipsastræa* and *Heliophyllum* is, however, not sufficient to allow

[1] F. Frech, Korallenfauna des Oberdevon in Deutschland, Zeitschrift der deutschen geol. Gesellschaft, vol. xxvii. p. 44, Berlin, 1885.

of a decided and conclusive opinion as to the degree of relationship between the two. Deeper investigations are needed, and for such I have not at present sufficient material, especially of *Heliophyllum*. I must confine myself to stating that I observed the same structure as in *Heliophyllum* in *Phillipsastræa Hennahii*, Lonsd., *Ph. Pengellyi*, E. & H., *Ph. Verneuilii*, E. & H.[1] and *Ph. gigas*, D. Owen, but I did not observe the same structure in *Ph. radiata*, S. Woodw., and *Ph. tuberosa*, M'Coy.

EXPLANATION OF FULL-PAGE WOODCUT (p. 403).

Enlarged figures showing the outline of the calices and the arrangement and the union of the septa. Taken from the type specimens of M'Coy in the Woodwardian Museum of Cambridge.

Fig. 1, 2, 3. *Phillipsastræa radiata*, S. Woodw. sp. (=*Sarcinula Phillipsi*, M'Coy).
Fig. 4, 5, 6. *Phillipsastræa tuberosa*, M'Coy, sp. (=*Sarcinula tuberosa*, M'Coy).

EXPLANATION OF PLATE XII.

Phillipsastræa radiata, S. Woodward sp. Carboniferous Limestone.

Fig. 1. Specimen from Haford-y-Calch, near Corwen, North Wales. Brit. Mus. [R 547]. Natural size.

Fig. 2. Specimen from Avon Section, near Bristol. Brit. Mus. [56740]. Calices more mammillated, approaching *Ph. tuberosa*, M'Coy. On other parts of the same specimen the surface is smoother. Natural size.

Fig. 3. Horizontal section of specimen, Brit. Mus. [R 547], showing the arrangement of septa and vesicles. Enlarged about 6½ times.

Fig. 4. Vertical section of specimen, Brit Mus. [R 547]. The lower part of the section shows the union of the septa in the central axes of the calices. The arrangement of tabulæ and vesicles is also shown. Enlarged about 8 times.

Fig. 5. Vertical section of specimen, Brit. Mus. [56740], showing the cone-shaped variety of the tabulæ. In other parts of the same specimen the tabulæ are more horizontal. Enlarged about 7 times.

Fig. 6. Specimen from Avon Section, near Bristol. (My collection.) Horizontal section across a corallite with cone-shaped tabulæ, represented as rings in the middle part of the corallite. Enlarged about 5 times.

Fig. 7. Specimen from Haford-y-Calch, near Corwen, North Wales. (My collection.) Horizontal section showing in the upper corallite the rudiments of a wall, which are drawn more faintly than the similarly-shaped vesicles. Enlarged about 4½ times.

Fig. 8. Horizontal section of specimen, Brit. Mus. [R 547], showing the minute structure of the septa and vesicles. Enlarged about 50 times.

Fig. 9. Vertical section of specimen, Brit. Mus. [R 547], showing the minute structure of the septa and tabulæ. Enlarged about 50 times.

VII.—Note on the Mean Rate of Subaërial Denudation.

By Charles Davison, M.A.,

Mathematical Master at King Edward's High School, Birmingham.

In his memoir on "Modern Denudation,"[2] Dr. A. Geikie determined approximately the number of years required by the following seven rivers to lower the general surface of their basins by one foot. He found that the Danube would take 6846 years, the Mississippi 6000, the Nith 4723, the Upper Ganges 2358, the Rhone 1528, the

[1] The above-mentioned structure is very well shown in a specimen, lent me by Dr. Hinde, for which kindness I owe him my best thanks.

[2] Glasgow Geol. Soc. Trans., vol. iii. p. 164.

Hoang Ho 1464, and the Po 729, years. The average of these figures is 3378, and "this," says Dr. Croll, in his recent interesting work on "Stellar Evolution" (p. 41), "gives a mean of 3378 years to remove one foot, or a little over one-half the time taken by the Mississippi." As the mean rate of subaërial denudation is an important element in physical geology, it may be worth while to point out a slight mistake in this determination of its value, and also to show how a more correct estimate may, with our present data, be obtained.

In the first place, let us, as in the above method, consider these river-basins of equal area for the purpose of ascertaining the mean rate of denudation. Then, in one year, a layer $\frac{1}{8848}$ of a foot thick is, on an average, worn away from the surface of the Danube basin, a layer $\frac{1}{6000}$ of a foot thick from that of the Mississippi, and so on. The mean thickness of the layers is the average of the seven fractions $\frac{1}{8848}$, $\frac{1}{6000}$, etc., *i.e.* $\frac{1}{1912}$ of a foot. This, and not the average of the denominators of these fractions, gives the mean rate of denudation on the above understanding: so that a layer one foot thick would be worn away from the general surface of the average river-basin in 1912, instead of in 3378, years. Or, if we take the area of the Upper Ganges basin at Dr. Haughton's estimate[1] of 143,000, in place of 432,480, square miles, the mean rate of denudation would be one foot in 1572, instead of in 3159, years.

But, in considering the river-basins as of equal size, undue importance is being given to such comparatively small rivers as the Rhone, the Nith, and the Po. In determining the mean rate of denudation, the *area* of each river-basin must evidently be taken into account, and this may be done as follows. The total volume of sediment brought down by these seven rivers every year is 34,712,610,040 cubic feet. If, as Dr. Geikie estimates, 25 cubic feet of sediment are derived from 19 cubic feet of rock,[2] this is equivalent to the removal of 26,380,817,398 cubic feet of rock; which may be regarded as taken from the surface of one river-basin equal in area to the sum of the areas of the above seven basins, *i.e.* to 2,279,400 square miles, or to 63,546,024,960,000 square feet. From these figures we find that the mean rate of subaërial denudation is equal to one foot every 2409 years, *i.e.* about two-fifths of the rate of denudation in the Mississippi basin.

Dr. Croll points out (p. 43) that the Rhone, the Ganges and the Po are charged with mud from the Alps or Himalayas; and, for this and other reasons, he makes use in his work of the rate of denudation in the Mississippi valley only. But while the rates of denudation in the above cases are among the most rapid, these rivers have at the same time (with the exception of the Nith, which hardly affects the average) the smallest basins; while the Danube, the

[1] A. Geikie, Text Book of Geology, p. 444, footnote. This value is used in the estimate that follows.

[2] Reckoning the specific gravity of the silt at 1·9 and that of rock at 2·5. This tends to diminish the estimate of the mean rate of denudation, for the sediment deposited at the mouth of a river is partly derived from the erosion of earthy beds.

Mississippi and the Hoang Ho, with less rapid rates of denudation, have the largest basins. The following table shows that it is the Mississippi, with its vast length and comparatively slight fall, that weighs excessively in the estimate of the average, rather than the Ganges or the Rhone or the Po.

	Mean rate of denudation, omitting the:		Excess above mean rate of all seven rivers.	
Mississippi	$\frac{1}{1524}$	foot per year. ...	+0·000241	foot per year.
Hoang Ho	$\frac{1}{3370}$	,, ...	−0·000118	,,
Upper Ganges ...	$\frac{1}{2765}$	,, ...	−0·000053	,,
Danube	$\frac{1}{2243}$	,, ...	+0·000031	,,
Po	$\frac{1}{2485}$	,, ...	−0·000013	,,
Rhone	$\frac{1}{2424}$	,, ...	−0·000002	,,
Nith	$\frac{1}{2409}$	,,	0·000000	,,

It thus appears that the rapid rates of denudation by the glacial rivers are to a great extent neutralised by the smallness of their basins. And, as such rivers ought not to be left out of account, it seems possible that the mean rate of subaërial denudation for the whole land-surface of the earth may not differ very greatly from that obtained above, namely, one foot in about 2400 years.

VIII.—Notes on the Lower Palæozoic Rocks of the Fichtelgebirge, Frankenwald, and Thüringerwald.

By J. E. Marr, M.A., Sec. G.S.,
St. John's College, Cambridge.

During the summer I visited Hof with Professor Nicholson, mainly in order to examine the Graptolite-bearing shales of the surrounding region. These we found to be far from rich in fossils, and the principal fossil-bearing localities were remote from one another. Under such circumstances little could have been accomplished, but for the kindness of Herr Glass, of Hof, who allowed us to examine his fine collection of fossils from the district. To him I would tender my best thanks, as also to Prof. Geinitz, who not only permitted me to examine his rich collection of Graptolites from the Thüringerwald preserved in the Dresden Museum, but also devoted some of his valuable time to me.

For a full account of the Lower Palæozoic rocks of the region under consideration, I may refer to Prof. Gümbel's exhaustive "Geognostiche Beschreibung des Fichtelgebirges mit dem Frankenwalde und dem Westlichen Vorlande." In that work the strata are grouped as under:—

Silurian.

Tentaculiten-Knollenkalk.
Upper Graptolite Shales.
Ockerkalk.
Lower Graptolite Shales.
Lower Silurian with Leimitz-shales, etc.

Cambrian.

Upper: Phycodenschichten.
Lower: Green-grey Clay Slates.

As Hof lies at no great distance from the Bohemian Basin, it might be expected that there would be considerable similarity

between the beds of the two areas, and in some respects this is the case, though the marked differences induced Barrande to infer the existence of a barrier between the two areas in Lower Palæozoic times. The differences may be accounted for in other ways; firstly, by the absence of some beds in Bohemia owing to unconformable overlap, and in Bavaria owing to faults, and secondly by the greater metamorphism of the Bavarian rocks. The effects of the latter have been described by Prof. Gümbel; the Cambrian beds are frequently converted into schists, the Ordovician into phyllites, and the Silurian into lydites, whilst the associated igneous rocks have also suffered much change, indeed the Fichtelgebirge furnish us with an admirable instance of later rocks having undergone regional metamorphism, and being infolded amongst other rocks which have been universally assigned to the Archæan.

Commencing with the Cambrian Rocks, the only fossils found in them are of very doubtful position, amongst these is *Phycodes circinatum*, which characterises the Phycodenschichten. The rocks are various coloured clay slates, and greywackes, sometimes converted into schists, as at Lamitzmühle, north-west of Hof, where the development of the schistose structure is admirably exhibited. Red beds are seen between Hof and Leimitz, and like similar Bohemian beds are possibly very low in the Cambrian system.

In the typical section at Leimitz the above-described beds are separated from the trilobitic shales of Leimitz by a dolomitic limestone; this is very possibly developed along a fault-plane, and would account for the apparent absence of the representatives of the Menevian and Lingula Flag series. The country here is so extremely faulted that rocks of very different ages are brought into juxtaposition. Not only are all the beds in the Leimitz section reversed, as shown in Murchison's section from the Labyrinthenberg to the Wartthurm (Q. J. G. S. 1863, p. 360); but it can be shown that in several places beds are faulted out, and the failure to discover Menevian and Lingula Flag fossils must not be taken as an indication of the original absence here of beds of these ages.

The next beds to notice, in ascending order, are the Leimitzschichten, though there is no necessity to linger over these, as not only has Barrande fully described the fauna ("Faune silurienne des Environs de Hof en Bavière," 1868), but Prof. Brögger has shown their close relationship with the Ceratopyge beds of Scandinavia, and the Shineton Shales of Shropshire ("Die silurischen Etagen 2 und 3").

In the Leuchtholz, near Lamitzmühle, is a gritty pisolitic ironstone, containing an *Orthis* compared by Dr. Gümbel with *Orthis Lindstrœmi*, Linnrs., whilst the rock containing it is referred to as possibly comparable with the Primordial beds. Concerning this deposit I would say something further. It occurs between the schistose Cambrian rocks of Lamitzmühle, and black phyllites and grey gritty shales near the village of Isaar. The latter are coloured in Dr. Gümbel's map with the Ordovician (Lower Silurian) colour, and though much altered they bear considerable resemblance to the beds of Barrande's étage D. Now, near the base of D, in Bohemia are found the pisolitic ironstones, D d 1 β, containing *Orthis deside-*

rata, Barr., seen at Krus'na Hora and elsewhere, and actually compared by Dr. Gümbel with the Leuchtholz ironstone. The latter I was unable to find *in situ*, but Herr Glass kindly presented me with specimens, and the *Orthis*, though badly preserved, is very near to, if not identical with *Orthis desiderata*, with which I have compared it. The reasons for the identity of the Bavarian and Bohemian deposits are similarity of lithological characters, close resemblance between the Orthides of the two, and the occurrence of both between Cambrian and Ordovician deposits.

In a paper read before the Geological Society (Q. J. G. S. 1880) I correlated the beds D d 1 β with Tremadoc beds, on account of their resemblance to the pisolitic ironstones of North Wales, their occurrence above sandstones full of *Lingula Feistmanteli*, and the existence of *Harpides Grimmi* in them. I believe, notwithstanding the occurrence of the latter fossil, that the reference was erroneous.

The Tremadoc age of the Welsh pisolitic ironstones has not been proved, indeed evidence has been published which indicates that they are much more modern. With regard to the occurrence of *Lingula Feistmanteli* in D d 1 *a*, this fossil has no relationship with any of the Lingula Flag fossils, but it is very near to the remarkable *Lingula Rouault* of the Armorican grits. Furthermore, the fauna of D d 1 γ is not a Lower but an Upper Arenig one, and the beds of this band immediately and conformably succeed those of D d 1 β. I am inclined therefore to refer the latter, and with it possibly the Leuchtholz deposit to a position high up in the Arenig series, and believe that the beds unconformably overlap the Cambrian rocks, thus accounting for the absence of Lower Arenigs in Bohemia and Bavaria, of Tremadocs and Lingula Flags in the former country, and of Menevians around a great part of the Bohemian basin.

We visited Hof, partly in hopes of detecting Graptolites of Hartfell and Glenkiln types in the Ordovician rocks; in this we were disappointed, nor did we find any trace of such fossils in Herr Glass's collection or in that of the Dresden Museum. I believe however that there are black shales of Ordovician age which have once contained Graptolites (*e.g.* the phyllites near Isaar) but with rocks so greatly altered, it is too much to expect their preservation.

Though rocks of the higher Ordovicians do probably occur in many places, they are elsewhere faulted out, as for instance at Leimitz, where the Lower Graptolite Shales are directly in contact with the Leimitz trilobitic shales. The former are here converted into lydite, but a few obscure graptolites were seen by us. *Clinacograptus normalis* was found here by Herr Glass, and the beds are undoubtedly the equivalents of our Stockdale Shales. In most of the localities near Hof these shales are now covered up, but in the Dresden Museum is preserved a slab from Teufelsberg with *Petalograptus palmeus* and *Monograptus Hisingeri*, indicating the Upper Skelgill beds, and Prof. Nicholson and myself have already recorded the existence of two slabs in the Woodwardian Museum indicating the existence of the *Monograptus fimbriatus* zone at Hof, whilst Herr Glass has *M. turriculatus* and *M. rectus* from Steben.

It is in the Frankenwald and Thüringerwald that the representatives of the Stockdale Shales are most fully developed, and at the risk of becoming monotonous, I give a list of species occurring together on the same slabs in the Dresden Museum, fully bearing out the wide distribution of those zones which we have determined in the Stockdale Shales of the Lake District. In this list the species given under one number occur on the same piece of stone.

OELZNITZ-JUCHHE.

1. *Monograptus fimbriatus, M. tenuis, Rastrites peregrinus, Climacograptus normalis, Diplograptus vesiculosus, Petalograptus ovatus.* = Zone of *Monograptus fimbriatus.*
2. *Monograptus fimbriatus, M. gregarius, M. attenuatus, Rastrites peregrinus, Climacograptus normalis, Petalograptus ovato-elongatus.* = Zone of *Monograptus fimbriatus.*
3. *Monograptus cyphus, M. tenuis, M. attenuatus, M. crenularis? Diplograptus sinuatus.* = Zone of *Monograptus fimbriatus?*

RAITZHAIN-RONNEBERG.

1. *Monograptus convolutus, M. proteus, Rastrites urceolus, R. hybridus.* = Zone of *Monograptus convolutus.*
2. *Monograptus spinigerus, M. jaculum, Petalograptus palmeus.* = Zone of *Monograptus spinigerus.*
3. *Rastrites maximus.* = Zone of *Rastrites maximus.*
4. *Monograptus turriculatus.* = Zone of *Monograptus turriculatus.*
5. *Monograptus exiguus, M. discus, Rastrites capillaris.* = Zone of *Monograptus crispus.*
6. *Monograptus M'Coyi, Cyrtograptus? spiralis, Petalograptus palmeus.* = Zone of *Monograptus crispus.*

LANGENSTRIEGIS.

1. *Monograptus jaculum, M. lobiferus, Petalograptus palmeus.* = Zone of *Monograptus spinigerus?*

LINDA.

1. *Monograptus pandus, M. Hisingeri, Retiolites Geinitzianus.* = Zone of *Monograptus crispus.*

HEINRICHSHOHE.

1. *Monograptus revolutus, Climacograptus normalis, Diplograptus vesiculosus, D.? longissimus.* = Zone of *Dimorphograptus confertus.*
2. *Monograptus attenuatus, M. revolotus? Petalograptus ovatus, Diplograptus sinuatus.* = Zone of *Monograptus fimbriatus.*
3. *Monograptus gregarius, Rastrites urceolus, R. hybridus, Petalograptus palmeus.* = Zone of *Monograptus convolutus?*
4. *Monograptus gregarius, M. Hisingeri, M. Becki, Rastrites urceolus, R. hybridus.* = Zone of *Monograptus convolutus?*
5. *Monograptus crassus, M. discretus, Rastrites hybridus.* = Zone of *Monograptus spinigerus.*
6. *Monograptus Nicoli, M. crassus? Diplograptus modestus.* = Zone of *Monograptus spinigerus.*

At Saalfeld a *Dimorphograptus* has been found, though the shales from this locality have been destroyed owing to the decomposition of pyrites.

The following zones which we have made out in the Stockdale shales are represented in Thuringia:—

Zone of *Dimorphograptus confertus.*
,, *Monograptus fimbriatus.*
,, ,, *convolutus.*
,, ,, *spinigerus.*
,, *Rastrites maximus.*
,, *Monograptus turriculatus.*
,, ,, *crispus.*

In short all our graptolitic zones except the insignificant and probably local zone of *Monograptus argenteus* occur here.

Before finally quitting the representatives of the Stockdale Shales, a word concerning the Nereites beds is necessary. These have been referred to the Devonian, and possibly forms like Nereites occur in the Devonian beds, but the specimens which Herr Glass collected at Bad Steben are so exactly like the Gala ones, both with reference to the lithological character of the containing rock, and the nature of the fossils, that I cannot help believing that they are of that age.

The Wenlock shales with *Cyrtograptus Murchisoni* are represented in Herr Glass's collection by specimens from Einzelnhöfen, with *Monograptus vomerinus, Cyrtograptus*, sp., *Cyrto.? spiralis*, and in the Dresden Museum by a specimen from Linda with *Monograptus priodon, M. vomerinus, Cyrtograptus*, sp., *C.? spiralis, Retiolites Geinitzianus.*

Above these shales lies the Ockerkalk with *Cardiola interrupta*, etc., and like the *Cardiola* beds of Sweden and the Lower Coldwell beds of Westmorland separating the *Cyrtograptus* beds from the beds with *Monograptus colonus.*

The latter are found at Gunzenberg near Plauen with *Monograptus Rœmeri*, and at Gräfenwarth near Schleiz with *Monograptus colonus* and *M bohemicus.*

Lastly, the Tentaculiten-knollenkalk with *Pterniea subfalcata, P. retroflexa*, etc., appears to represent the Upper Ludlow beds of Britain, and the limestone of E. 2 in Bohemia.

Beds of higher age, such as the *Styliola* beds and Goniatite limestones are probably comparable with higher stages of the Bohemian basin, which they altogether resemble, thus yielding additional evidence of the accuracy of Prof. Kayser's view as to the age of stages F, G, and H. As I understand that Herr Frech has visited the Hof district in order to examine these Devonian rocks, further discussion is rendered unnecessary.

The result of the cursory examination of the area has been to show that the difference between the Bohemian and Bavarian beds is by no means great, where beds of the same age can be compared, and that even our British deposits are in many cases represented by many similar strata in Bavaria, and the Thüringerwald; that this is specially the case with the graptolite-bearing shales and adds one more instance to those which have been adduced to prove the value of these forms in marking stratigraphical horizons.

IX.—On the Scratched and Facetted Stones of the Salt Range, India.

By Professor George H. Stone.

At the Meeting of the British Association in 1886, a facetted and striated pebble from the Salt Range, Punjab, was exhibited and described, by A. B. Wynne, F.G.S. Another and larger one was presented by Dr. W. T. Blanford, F.R.S.[1]

[1] Geol. Mag. 1886, Dec. III. Vol. III. pp. 492, 494, and p. 574.

During the discussion that ensued, the question was considered whether the stones had received their shapes from the action of wind-blown sand. Having made a special study of sand-carving in a favourable region, the writer became interested in the subject, and with a view to compare the Punjab stones with the sand-facetted rock-fragments so common in various parts of America, wrote to Dr. Blanford in order to obtain specimens of the stones in question. By the kindness of Dr. Blanford and Mr. Wynne, plaster casts of both the specimens described by them have been sent to me. Dr. Blanford also put me into communication with Dr. Henry Warth, who has kindly sent me three of the scratched stones which he had found in the field. It is the object of the present paper not to enter upon the large question of a Glacial period in Palæozoic or Mesozoic time, but briefly to consider the testimony of the specimens about to be described as to their own origin. Most of the conclusions arrived at have been anticipated by those who have discussed the origin of the shapes of these particular specimens.[1]

Yet conclusions drawn from observations made in widely removed regions have a comparative value; therefore, at the risk of repeating what has been observed elsewhere, the facts are here recorded which, observed in Colorado and Maine, throw light on the origin of the markings on the stones in question. The existence of a Glacial period can only be proved by the whole mass of field evidence, and this can only be worked out by the geologists on the ground. In solving the general problem it will be necessary first of all to determine the manner in which the stones and boulders were facetted and scratched. Afterwards comes the question how they were brought to their present positions in the midst of clay or sand. Evidently a study of the markings on the stones can afford little direct evidence except on the first of these questions.

The specimens in my possession are the following.

No. 1. This is a plaster cast of the stone exhibited before the British Association by Mr. Wynne. The form is not that which would be caused by the wind.

No. 2. A plaster cast of the stone described by Dr. Blanford. The cast, Dr. Blanford informs me by letter, does not show the scratches as plainly as the original. Yet the scratches on the facets are so readily distinguished that a friend, a mining engineer, who happened to be present when the cast was received, at once exclaimed: "Why it looks as if it had been in a Mexican arastra." The scratches are not such as could be produced by blowing sand or gravel.

No. 3. Forwarded to me from Stuttgart by direction of Dr. Warth. It is composed of a dark red felsitic ground-mass, containing many crystals and grains of a lighter red felspar, with some free quartz and small quantities of one or more accessory minerals. All fracture surfaces of the stone are quite uneven. On breaking off a portion

[1] Including in addition to the original articles of Dr. Blanford and Mr. Wynne, communications by Mr. R. D. Oldham, Geol. Mag. Jan. 1887, and from Rev. A. Irving, Geol. Mag. April, 1887. Similar specimens are discussed by Dr. H. Warth, Records Geol. Survey of India, vol. xxi. pt. 1, 1888.

of the stone the fresh surface was seen to be of a lighter and more rosy colour than the original surface. The felspar grains and crystals of the surface are perceptibly roughened. The stone is thus proved to be weathered, though the discoloured layer is quite thin. The composition and structure of the porphyry indicate that it is a very enduring rock. The striated surfaces, even at the bottom of the broader scratches, are apparently as much weathered as the rest of the stone. There are four principal planed facets, and their sides are nearly parallel like those of the faces of a prism. One face is nearly plane, the others have a curved or broken-curved cross-section. The facets have been reduced to an even surface and afford a marked contrast to the rough fracture surfaces. The scratches are quite straight and distinct, though their sides are not so sharply defined as is usual on recently facetted stones. The whole outer surface has received a fine polish, such that the apices of the larger projections have been rounded and the smaller ones nearly erased. The stone is three inches and three-quarters in length, and its greatest transverse diameter is two inches and three-quarters. The angles between the facets are not sharp, partly in consequence of the fine polish before described, and partly because the planed surfaces do not in general meet, but are separated by a narrow strip of unplaned surface retaining the uneven form due to fracture, except as it has been modified by the fine polish before mentioned.

No. 4. Sent to me direct from India by courtesy of a returning missionary. Diameters, two inches and an eighth to three inches and a half. It is composed of a light red porphyry. Most of the larger grains and imperfect crystals of felspar which are exposed on the planed facets have weathered so as to be quite rough. There are a number of small irregular depressions on the planed faces caused by the partial weathering of the less resistant grains. The smooth facets are arranged about an axis roughly after the manner of the faces of a prism, and one end of the imperfect prism thus formed is also planed. The remainder of the surface is uneven, and is simply a fracture-surface modified by a fine polish, which has removed the apices of the angles and the smallest of the projecting points. Some of the faces do not show distinct scratches, though planed to a flat and even surface. The surface of this specimen has been more modified by weathering than No. 3. The weathering involves the bottom of the scratches as well as the unscratched surfaces, and there is little, if any, difference in the depth of the weathering in different parts of the stone.

No. 5. Also sent direct from India. It is about three inches long. It is a fragment recently broken off from a water-rounded cobble that was probably about six inches in diameter. It is composed of compact, fine-grained quartzite, which here and there contains microscopic grains of felspar. One portion of the cobble has been distinctly planed and scratched. At least one quarter of an inch has been ground away from the stone, if we estimate its original shape from the curves of the rounded portion of the stone adjacent to the planed facet. The scratched surface presents gentle undulations

both parallel to the scratches and transverse to them. Particular scratches or grooves can be traced for two or three inches across the whole facet, though in general the smaller scratches are not so distinct as those on the porphyry, and they often become confluent. On the planed facet some of the felspar grains preserve their polish, except at the edges; others are weathered so as to be uneven, as also are those on the rounded portion of the stone. This specimen shows less weathering than Numbers 3 and 4.

Cause of the Striation and Facetting.

First.—All who have seen the stones agree that they have a genuine and ancient look. They have either been weathered since they were scratched, or the surface has been treated with corrosive acids not found in the field. The number of places where they have been found is inconsistent with such an accident. Most of the scratches are too straight and parallel, also too broad and deep to have been made by the unassisted hand. The scratches on No. 5 might perhaps have been made in such a machine as the arastra. The facets on the others might be produced on a grindstone if the stones were held very firmly. The stones resemble no stone implement, and are not fashioned for use. If ground by man, it must have been for purposes of deception or for grinding something else. In either case it could not have been the act of a Palæolithic man, but of one furnished with modern machinery. The evidence of the stones points to their having been ground and striated a very long time ago. Their testimony thus unites with the field evidence as to the distribution of the stones over wide areas, their situations on the tops of mountains, often remote from places likely to have been inhabited, their being found independently by several different observers, their being associated with the outcrops of certain boulder-beds, etc., to prove that the stones were not the work of man.

Second.—Some, perhaps all, of the specimens have been subjected to a limited amount of polishing since they were facetted. The larger inequalities of the fracture-surfaces remain, yet the surface of both the projections and the shallower hollows has been distinctly smoothed. This is of the same sort as would result from a very limited amount of water-wear, also that resulting from soilcap movement. For instance, in the Rocky Mountains the miners' "float rock" is often found from one-fourth of a mile up to one mile or more from the parent vein. Reference is made not to the stones transported by running water, but to those of the talus or angular gravel which covers the slopes of a large portion of the mountains. This mass of disintegrated rock is a sort of mineral glacier slowly sliding down the mountains, and even the hard vein quartz is usually perceptibly smoothed by the attrition of the earth and stones with which it has come in contact during its journey. The same sort of polish is not seldom found on the harder fragments situated on the talus at the base of a scarp of erosion of sedimentary rock. During the disintegration of the boulder-bed of the Olive group such friction would have helped to smooth the stones in ques-

tion, as has been suggested by several of the writers on this subject. Here in the Rocky Mountains there are fine facilities for studying soilcap movement, and without exception the instances of it observed by me show only a limited amount of polishing, the apices of the angles being rounded and the surface smoothed without being reduced to a plane like the facets of the Punjab specimens. The soilcap polish is substantially like that which the facetted stones have received since they were facetted. But I have never found, on any piece of float-rock, scratching that in kind or degree resembled the planed and striated facets of the stones under discussion. There is a satisfactory reason for this. The slowness of soilcap movement gives time for the stones to accommodate themselves partially to each other's movements. If the friction were to become great enough to produce such wide and deep scratches as appear on the planed facets of the stones in question, they would partly roll past each other rather than slide. It seems to be certain that the "glaciated" stones have been polished since they were scratched, and this fine polish could be caused by soilcap movement or by a limited amount of water-wear.

Third.—The formation of distinct scratches constitutes a problem distinct from that of the planing to an even surface. Could the scratches have been formed by wind-blown sand or gravel? Scratches may be made, first, by a point rubbing against a surface and being held in the same relative position towards it; second, by a rolling body crushing its way into a softer or more brittle surface; third, both these processes may combine to produce the scratches. It is evident that grinding by the use of loose powders involves the second and third of these processes, while planing and the use of grindstones involve the first, and produce scratches having an even and sharply-defined margin.

Grains of sand and gravel stones when impelled by the wind or by moving water have a rolling as well as a sliding motion. This I know to be the fact from observation, though it is easy to prove that this must be the natural mechanical result of friction applied to one side of a moving solid that is surrounded by a liquid or a gas. As a body of irregular shape, like grains of sand and gravel stones, rolls, or partly rolls, partly slides upon another body, new points of the moving body are continually brought into contact with the stationary body, and since the shape is irregular, the new point of contact will usually be situated to one side of the original point, and the track of the grain will necessarily be crooked. If an irregular grain be impelled in a straight line, it cannot often preserve its direction in the same vertical plane after rebounding, for the friction will be applied to one side of the vertical plane in which is situated the centre of gravity of the body, and the grain will be thrown obliquely sideways. So, too, air and water are constantly being thrown into vortices by the inequalities of the surfaces over which they move. For these reasons it must seldom, if ever, happen that wind or water can impel sand or gravel with the steady motion required in order to produce long straight scratches. The larger stones often produce

scratches that can be distinguished by the unassisted eye, but they are seldom more than a small fraction of an inch in length. Here, in the Rocky Mountains, the finer dust broadens these larger scratches more than it deepens them, so that they are soon obliterated or changed to shallow grooves. Stones one-fourth to half an inch in diameter are frequently transported by the winter winds, and the flying gravel is sometimes so painful that horses cannot be made to face it, and I know of a blue eye-shade that was broken by gravel while the wearer was facing a Chinook wind in Colorado.

Now the scratches of these Salt Range stones have sharply-defined borders, and they are two inches or somewhat less in length, and most of them very straight. The graving tools that produced them moved with a very steady motion, and the depth is such, that a considerable force was required. The hypothesis that under any conditions blowing sand or gravel could produce such scratches may once for all be confidently rejected.

Fourth.—Assuming that the scratching could not be caused by wind action, could the facetting be so caused?

We may classify with sufficient accuracy for our present purpose the conditions under which facetting is done by the wind as follows. First, where the upper surface of a stone only a few inches in diameter lies nearly on the same level as the surface of the soil or of other stones around it. The small stone often has its upper surface ground away to near the level of the adjacent earth, and often has its form determined by the shape of the adjoining bodies. It is surprising how flat many of these small facets are, especially when the stone is homogeneous in composition. Examination of many facets shows a tendency to form a gently undulating surface, the crests of the low undulations more often being transverse to the direction of the wind and an inch or more apart. In the class under consideration the stone is so small, and is so far protected by the adjacent bodies, that a large part of the carving is done by flying grains as they first strike the stone, at which time their motion had been in great measure determined by the adjacent land surface.

If in any way one of these small stones becomes overturned, a new facet may be formed in the same manner.

A somewhat different case is presented when a stone or boulder projects considerably above the ground, or has a large and nearly horizontal surface near the ground. In this case a much larger proportion of the grinding is done after the blowing stones have once rebounded from the fixed stone. The rhythmical friction of the wind against the fixed stone and the repeated reboundings in this case determine the character of the carving more than the direction of original impact. The sand-carved surface under these circumstances is usually covered by shallow grooves parallel with the direction of the prevailing wind. This form of carving appears to be related to the oblique reboundings of the grains sidewise. The grooves are an inch or less in breadth and seldom more than the sixteenth of an inch in depth. The difference between the two

forms of sand-carving may be illustrated by sea-waves and true water undulations. In the undulations the crests are convex above, in the wind waves they are bounded by two concave surfaces meeting in a somewhat blunt angle. But the undulations of the sand-carved surfaces are more often transverse to the wind like ripple-marks, while the concave grooves are parallel to it. The two forms are often superposed, so that a large number of the concave grooves can not seldom be traced up and over a long transverse undulation, or they give rise to a large number of conchoidal depressions.

Where the stones project considerably above the ground, several faces are usually being polished simultaneously or as the wind changes. At the base of the Rockies the plains are strewn with multitudes of granite-drift boulders from the mountains. One can hardly go a hundred feet on these plains without finding boulders presenting polished facets in all positions with respect to both vertical and horizontal planes. A single boulder may have a dozen or more facets, just as if one could polish up the Matterhorn, leaving its arrêtes as so many facet-angles extending downward and outward in all directions. The angles between adjacent facets are terminated by rather short convex curves, so that they are somewhat rounded, not true mineralogical angles. The grooves often have different directions on different faces; but in places where the wind can only act when blowing in a certain direction, they are parallel. They can often be traced up to a facet angle and around on to the next facet, especially when the angle is quite obtuse. Grooves can be found at all angles to facet edges, both parallel and transverse to them. The positions of the facets of a given stone are evidently determined partly by the original shape of the stone and partly by the accidents of the grinding process. The facts in Colorado abundantly prove that several facets can be formed contemporaneously, and that it is not necessary in all cases to premise a change of position of the stone when more than one facet is found. These observations, especially those relating to the angles which the conchoidal grooves make with the facet edges, differ from those of Mr. Oldham. This perhaps may be due to the wind being more constant in direction in India than in Colorado. Here the prevailing direction of the grooves is north-west, but sand and gravel are transported by winds from the north, west, and sometimes from the south or south-west.

The conclusion follows that the facetting of the Punjab specimens might be simulated by wind action, but not the flat, almost plane surfaces of the facets.

Fifth.—Were the scratching and facetting done by glacier-ice? This is the opinion of Messrs. Blanford, Oldham, and Wynne; but the Rev. A. Irving objects (*loc. cit.*) that during extensive observations in the Alps, he has not seen stones facetted like these.

The writer has carefully examined the moraines of the local glaciers of the White Mountains in New Hampshire, also those of the Rocky Mountains, and never has found stones facetted in so many planes as the stones in question. In this respect my observations exactly accord with those of Mr. Irving. But in the lower

portion of the till of Maine there are literally multitudes of stones glaciated on all sides and often in flat facets like the specimens under discussion. American geologists are now nearly unanimously in accord with the Swedish geologists Torell and Holst that the lower part of the till of New England was a ground moraine beneath an ice-sheet, while much morainal matter was distributed through the lower part of the ice. The stones under this deep sheet of ice were much more intensely glaciated than in the case of the shallower valley glaciers. It is not needful now to go into the discussion of the molecular physics of glaciers. If it be affirmed that glacier ice is too fluid (or plastic) to hold stones long enough and firmly enough to permit them to be facetted and violently scratched, the matter can be decided by an appeal to the ground moraine of the New England ice-sheet. The only way to escape the conclusion that land-ice can scratch and facet stones like the Punjab specimens is by denying that New England was covered with land-ice. But the hypothesis of the glacier origin of the till of New England was never more strongly entrenched than at present. Every year since the days of Agassiz has brought new confirmation. The terminal moraines, the osar marking, the courses of the long glacier rivers, and all the other marks of land-ice, constitute overwhelming proofs of the reality of that ice-sheet.

I conclude that both the facetting and the striation of the specimens under review are of the same kind that in geological time past have been wrought by glacier-ice of considerable thickness.

Sixth.—Could the scratching and facetting have been produced during a landslip? No observations of stones being planed during a landslip have been recorded in America so far as I know. Yet it is extremely improbable that a landslip could occur without attrition of the stones involved. The flames seen at the great slip at Goldau indicate an evolution of molecular heat that could only be caused by great friction resulting in a large amount of crushed rock. During the land-slip the motion is so rapid that the stones would not have much time to roll into new positions; yet where so much work is being done, it is difficult to place a limit to the kind of work we can admit as probable. While, then, no evidence is offered to the effect that direct observation shows that stones such as the Salt Range specimens have been scratched and ground to flat facets during landslips, yet when we consider the forces involved and the great energy of action, it appears highly probable that landslips might produce such a kind of work.

The scratching has plainly not been produced by a modern landslip, unless in the case of specimen No. 5. The weathered condition of the facets proves that the scratching was done before the deposition of the specimens in the boulder-bed, or simultaneously with it.

On the whole I see no cause afforded by the facts now known sufficient to warrant denying that such forms as those under discussion might be produced during landslips of large masses for a considerable distance.

Seventh.—Could the scratchings be produced by fault-movements?

In several cases I have found in the fault-breccia stones that had been scratched, though none of them were facetted in so many planes as these. In the movements of faulted rocks we certainly have an agency capable of a steady motion and powerful enough to plane the hardest rocks. The facets of these specimens are not so smooth as ordinary slickensides on large masses of rock. Most of these scratches were made by graving tools not yet dulled by long friction. No. 5 may have been produced by a recent fault, the others must have been striated before deposition. The hypothesis that these stones were once a part of the fault-breccia would postulate faults occurring before the deposition of the boulder-bed, a portion of the breccia becoming in time exposed on the surface by the decay of the rock on each side of the fault, and the stones subsequently being carried by some means into the boulder-bed. There is much here that is unknown, yet every hypothesis that alleges a cause sufficient for the required work is entitled to a hearing and a fair decision according to the whole evidence.

Eighth.—Were the markings caused by floating-ice? Mr. Oldham (*loc. cit.*) well sets forth the uncertainties regarding the work of ice-floes or bergs upon the stones contained within them. No one seems to have seen shore-ice or any other form of floating-ice facetting stones like the Salt Range specimens. The writer has visited several places on the coast of Maine where ice-floes had been driven ashore with such force as to pile up blocks of ice to the depth of ten to twenty feet. The shore was left strewn with stones and even large boulders four to six feet in diameter. The scratches on the stones were very irregular, in no way resembling those of the stones under discussion. The shore-ice during the rise and fall of the tides produces on the coast of Maine no such markings and planing. Bergs and thick floes would be less easily broken into blocks and might have greater power to facet stones than the shore-ice of Maine. In the present state of the argument floating-ice must be regarded as one of the possible agencies for facetting stones, yet one concerning which little is positively known. River-ice, especially at the time of the breaking of an ice gorge, is here included under the term floating-ice.

The expansion of lake and river-ice produces scratches on the stones of the beach, but no such regular striation and facetting as that under consideration, and large stones driven swiftly along by water can be scratched, but not in a way like these.

The only natural agencies that seem to be adequate to produce such straight scratches and such flat facets as those of the Salt Range stones that have occurred to me are glacier- and floating-ice, landslips, and fault-movements; and concerning three of these agencies but little is known by direct observation. They must, however, be adequately considered before the theory of glacier-ice can be regarded as fully established, though the glacial hypothesis is not inconsistent with our supposing that part of the stones were formed in some other way than by glacier-ice. In the absence of direct observation of the stones involved in landslips, fault-

movements and floating-ice, no test can be named whereby to distinguish stones scratched in these ways from those of the glacier. In other words, in the present state of the argument, the scratching and facetting of the stones do not reveal their origin with certainty. Until proper tests are devised, we must rely on the general field evidence. Some progress can, however, be reported, for the facts certainly prove that the Salt Range specimens are not due to wind or water action. This narrows the field of future research somewhat. It is desirable that observations of the stones involved in the other processes named should be studied as carefully as those of the glacier have been.

It will be noted that the above stated conclusions are based solely on the nature of the markings on the specimens. These specimens are all the material I have for an inductive argument. The general argument in several ways will enable us to distinguish to some extent between the agencies above named as possible causes of the striation, but the matter is for the present left to those who have studied the phenomena in the field.

Four of the specimens described were not much, if in any way, worn by water. They were not, therefore, transported to their position in the midst of clay or sand by running water acting upon them under ordinary conditions. The writer has seen boulders four feet in diameter transported by the rush of water during a cloud-burst in Colorado, and left in the midst of mud and fine sand. If the boulder-bed were formed subaerially, and in a region of severe and sudden storms, the smaller boulders might possibly be accounted for as due to the rush of rapid waters over a soil deposited by rains of ordinary kind. Such a soil if subsequently eroded by the sea or a lake would become stratified and would contain the boulders previously strewn over the region, they being little, if at all, rounded during the erosion of the mud and soil.

Still another method can be named for transporting the scratched stones and boulders to their present positions in the midst of clay or sand. A water-logged stratum of clay or shale is more likely to cause a landslip than any other kind of rock. Suppose such a mass of sedimentary clay to have been deposited over crystalline porphyries previously shattered into boulders of decomposition. If afterwards the region is elevated so as to become part of a mountain range adjacent to the sea or a lake, subaerial erosion would begin to lay bare the underlying rocks, and the waves would form a zone of shingle along the beach. If, subsequently, landslips should occur along the mountain-sides, the clay would carry with it into the sea or lake many of the underlying boulders of decomposition and portions of the beach gravels. Many of the stones might be facetted and striated during the landslip, and we should now find them scattered through the clay or sand involved in the slip. And if this clay or sand were subsequently eroded by the lake or sea-waves, the larger stones would still be left in the midst of the fine material, being but little worn or polished during the process.

The hypothesis of the stones and boulders found in the midst of

the fine sediments having been dropped by floating-ice also well accounts for the deposition of the boulders without much water-wear. This was the theory suggested by Dr. Blanford many years ago, and on the whole is the most probable of any of the theories suggested. It may be that these boulders were not all transported in the same manner. The clays and sands that were formed off the shore of the sea in Maine during the "Champlain" elevation of the sea are strewn with erratic boulders up to twenty feet in diameter. The clays are fossiliferous and must have been formed in the open sea. The boulders were dropped from floes of shore-ice or small bergs. Every winter the shore-ice becomes attached to boulders, and in the spring these boulders are carried out to sea and along the coast when the ice becomes detached from the shore. This hypothesis therefore postulates a process that is known by actual observation to be an efficient one.

It is not the writer's purpose, however, to enter on the general question. The character of the specimens imperatively demands some method of transportation that did not involve much water-wear and permitted the preservation of the scratches on the surface. But the specimens afford little evidence as to the exact manner of their transportation.

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X.—On the Greenstone and Associated Rocks of the Manacle Point, Lizard.

By Alexander Somervail.

ON De La Beche's Geological Survey Map of Cornwall are three colours representing the associated rocks at, and on each side of the Manacle Point. The Point itself and for a considerable distance south of it is represented as a greenstone. Partially encased in the greenstone and to the south of it is gabbro, which forms the main mass of this rock in the Lizard district. On the north side of the greenstone which forms the extreme south wall of Porthonstock Cove is hornblende-schist, which with some serpentine and other rocks terminates against the killas, or slates near Porthalla.

Several observers with seeming good reason have drawn attention to the fact that the greenstone as represented on the map is made to cover much too large an area to the south, and that any one walking from this direction, or the reverse, finds gabbro where the former rock was expected to occur. That this is the case, there is absolutely no doubt, but, De La Beche may have had his own reasons for this, although perhaps not distinctly stated in the text of his accompanying memoir.

Not only does this seeming discrepancy exist with regard to the relative extent of these rocks, but one also soon seems to get involved in another with regard to their relative ages.

It has been taken for granted somehow or other that the greenstone is the newer rock, as it seems to cut the gabbro; but at Porthonstock this is entirely reversed, the gabbro in several instances traversing the greenstone.

From the commencement of the greenstone on the south side of Porthonstock Cove, as indicated on the map, there is little more than a repetition of alternate greenstone and gabbro for a considerable distance to the south. At first the greenstone is the predominating rock for a short distance, then both almost in equal proportions. The gabbro in its turn, however, soon preponderates, yet still having a number of bands or veins of the greenstone, these becoming fewer as the central mass of the gabbro is reached.

These bands and veins of greenstone differ considerably from each other seemingly in proportion to their width and in their relations from the more central mass of the gabbro. Some of them are like dolerites, others like diorites, and both are frequently porphyritic, and not to be distinguished from similar rocks much further south associated with the granulitic group which cuts the serpentine.

These veins, where I first saw them near the southern limit of the greenstone on the map, firmly impressed me with the conviction that they were due to segregation. During a moderate falling rain I was able to examine them to much advantage, the wet on the rock brings out the very decided way in which the veins shaded into the matrix of the gabbro. Repeated examples bore out the same conclusion, and the broader bands pass in a similar way into the mass of the gabbro, without the slightest sign of intrusion, or of any force having been exerted, or the margins of either having been altered in the very least degree by contact.

The example already referred to of the Porthonstock gabbro traversing the greenstone, so apparently contradictory, is also, I believe, due to segregation from the more extensive mass of the greenstone occurring at this point; so that on the ground of segregation, anomalies and difficulties at once disappear. I have no doubt that it was from the successive bands of both rocks at Porthonstock Point, that De La Beche was induced to colour so much of this area as greenstone, if not from the very reason just given.

There can be no doubt but that the greenstone and gabbro are portions of one and the same magma, the gabbro on its northern margin passing into the former, and as we shall presently see, the hornblende schists immediately north of the greenstone are formed out of this latter rock,[1] so that all three—gabbro, greenstone, and hornblende-schist—are but the modifications chemically and mechanically of one mass, although represented by the three colours alluded to. From south to north, as already stated, there is a gradually growing disposition on the part of the gabbro to become more split up by the segregated greenstone veins and bands, until these become the dominant rock at and north of Porthonstock, resulting in what is now represented by the hornblende-schists north of that locality.

The greenstone of Porthonstock is not by any means a rock that has undergone any very great amount of secondary alteration. Immediately north of it, however, there is evidence of a plane of great disturbance which has much more completely altered its original constituents, especially its augite into hornblende, and pro-

[1] This opinion is expressed in Prof. Sedgwick's paper, Trans. Cambridge Phil. Soc. vol. i. p. 18.

duced a highly schistose structure. Its various mineral constituents are much crushed, flattened and broken up into fine fragments, the long axes of which conform more or less to the planes of cleavage produced by the great mechanical pressure the rock has here undergone. The original porphyritic structure, though much crushed, is yet distinctly traceable, and further north, where the rock is less cleaved or schistose, as towards Porthkerris Cove, and Point, the porphyritic structure much abounds.

There is another point with regard to the Porthonstock greenstone which must not be overlooked, that is, the tendency of the rock in parts to assume the granulitic structure, which, although on a small scale here, is yet the same type of rock as met with in the southern areas. This also is, I contend, but a portion separated from the greenstone by segregation, so that from the parent mass of the gabbro has been evolved the granulitic and the greenstone, which latter by subsequent dynamical movements has been converted into hornblende-schist.

This explanation I am inclined to regard as no mere speculation, but as a fair and just inference based on what we can observe in many localities at the Lizard. In some of these localities all three rocks, gabbro, granulitic, and hornblende, are more or less interchangeable, and a distinct passage can be traced between them all. In certain areas large tracts of the latter rock, which seems to have formed the upper or outer margin of the gabbro, have been cleaved into what now form the schists, while the more granulitic portions, although closely adjoining, have from their coarse and granular nature been much less affected.

It will, I think, be ultimately found that segregation has played a most important part among all the rocks of the Lizard district. The bands of hornblende so frequently occurring in the serpentine in various localities are due, I think, to this cause. The dykes in the outer rocks off the Lizard Head, mapped with such care, and not without danger, by Mr. Howard Fox, F.G.S.,[1] are, I believe, true segregation dykes. The banded structure in the hornblende-schists and associated gneissic rocks is also in my opinion due to this same cause, a subject I hope to deal with very shortly.

If the present suggestion is correct, in reducing the triple division of the rocks at the Manacle Point to mere varieties of one original magma, it seems to go a long way towards simplifying the geology of the rest of this most interesting district.

NOTICES OF MEMOIRS.

1. "On a Head of *Hybodus Delabechii*, associated with Dorsal Fin-spines, from the Lower Lias of Lyme Regis, Dorsetshire." By A. Smith Woodward. Ann. Report Yorksh. Phil. Soc. 1888, pp. 58–61, pl. i.

THROUGH the generosity of Mr. William Reed, F.G.S., the Yorkshire Philosophical Society is enabled to publish, in its recently-issued Report for 1888, a fine quarto plate (drawn by Miss G. M.

[1] On the Gneissic Rocks off the Lizard, Q.J.G.S. May, 1888, p. 309.

Woodward) of the most perfectly preserved head of the Liassic Shark, *Hybodus Delabechei*, hitherto discovered. The specimen is contained in the Reed Collection of the York Museum and exhibits, for the first time, the precise arrangement and relative proportions of the teeth, in addition to some of the characters of the cranial cartilage. The mandibular teeth are disposed upon each ramus of the jaw in ten or eleven transverse series, being thus more numerous than in *Acrodus*; and there is no azygous series of symphysial teeth. The dorsal covering of shagreen is sparse, and the absence of barbed, lateral head-spines is somewhat remarkable.

2. Fish Remains from the Lower Coal Measures of Lancashire. By Herbert Bolton. Trans. Manchester Geol. Soc. vol. xx. pt. viii. 1889.

THE author records the occurrence of fossil fish remains in shale overlying the Upper Foot, or Bullion Mine Coal, in Rossendale, and publishes brief notes upon the specimens. A large *Elonichthys* appears to be referable to *E. semistriatus*, Traq.; a head of *Cœlacanthus* is shown to differ in some respects from that of the common *C. lepturus*; and other less satisfactory fragments do not permit of any tolerably precise determination.

3. "Ueber zwei Fische aus den Angulatuskalken des Unter-Elsass." By W. Deecke. Mittheil. Commission geol. Landes-Untersuch. Elsass-Lothringen, vol. i. 1888. 11 pp. 1 pl.

THE author describes a new species of *Heterolepidotus* and another of *Dapedius* from the Angulatus-beds of Alsace, and claims these to be the oldest Liassic fish-remains hitherto discovered. *Heterolepidotus angulati* is founded upon the well-preserved trunk of a typical member of the genus, closely related to *H. serrulatus*, but differing in the smoothness of the scales. Of *Dapedius cycloides*, a complete fish forms the type-specimen, and this seems to differ from the well-known *D. orbis* of Barrow-on-Soar, merely in the prominent sculpturing of the scales upon the foremost half of the trunk. Of the *Heterolepidotus* a description alone is given; but of the *Dapedius* there is a good photograph, with explanatory lettering upon a traced outline of the fossil.

REVIEWS.

I.—The Middle Lias of Northamptonshire. By Beeby Thompson, F.G.S., F.C.S. (London, Simpkin, Marshall, & Co.) 8vo. pp. 150. Price 3*s.* 6*d.*

SINCE the days when Samuel Sharp laboured so successfully among the Oolites of Northamptonshire, no one has studied more assiduously the county geology than the author of the present work. Confining his attention mainly to the country accessible from the town of Northampton, he has added largely to our knowledge of the Upper Lias, in papers published in the Journal of the Northamptonshire Natural History Society; and he now gives us the

results of his observations on the Middle Lias. The work itself has appeared in serial form in the "Midland Naturalist," but the author has done well to reprint his papers in a neat and handy volume, and so save them from the oblivion which too often befalls many excellent articles.

Two main subjects are treated of and discussed: 1, the Middle Lias, stratigraphically and palæontologically; and 2, the Strata in their connection with Water-supply, etc.

In the first portion we are given detailed notes of many sections, and, what is of most importance, records of fossils obtained from each minor division of the strata. When we learn that these divisions amount to thirteen in all, we may confidently assert that the position of each assemblage of fossils in the Middle Lias has been worked out much more minutely than in any other area in this country. In saying so much, we do not attach undue importance to these minor or perhaps local divisions; but inasmuch as the author founds his work on the stratigraphical sequence of the beds, his facts and conclusions will be of great value to other workers, who are endeavouring to trace out the biological history of the species.

Some forms are for the first time recorded from the strata in this country; while others altogether new, obtained by the author, and by another zealous worker, Mr. W. D. Crick, have been recently described by Mr. E. Wilson in the pages of this MAGAZINE.

The so-called "Transition-bed" between the Middle and Upper Lias, a bed previously discovered and worked out on the borders of Oxfordshire and Northamptonshire by Mr. T. Beesley and Mr. E. A. Walford, is described as fully as possible. Stratigraphically it is a very insignificant bed, but a few inches in thickness, so that whether it be regarded as Middle or Upper Lias is a question in no ways calculated to disturb the mind of the geological surveyor. It has yielded a fauna of upwards of 90 species—about three-fourths of which belong to the Middle Lias and one-fourth to the Upper Lias. The Ammonites are essentially Upper Lias types, and these include the characteristic *Ammonites acutus*. The Gasteropods are of Middle Lias character and suggest that the bed is approximately on the same horizon as the '*Pleurotomaria*-bed' (of Mr. E. C. H. Day) on the Dorsetshire coast.

Mr. Thompson includes in his Middle Lias only the zones of *Ammonites spinatus* and *A. margaritatus*; thus putting the beds with *A. capricornus*, *A. Henleyi*, etc., in the Lower Lias—a grouping adopted by the Geological Survey. All the evidence, however, goes to show that the larger as well as the smaller divisions are intimately linked, and the Upper Lias beds in Northamptonshire appear in places to be closely connected with the Northampton Sands, as pointed out elsewhere by the author.

Passing on to the second portion of this work, we find a notice of the Economic products, and then a general account of the Springs in the Gravels and Oolites. The latter portion of this subject is but introductory to a special account of the water-bearing beds of the Middle Lias.

Owing to the increased amount of water needed for the town of Northampton, and partly owing to improved systems of agricultural drainage, the water derived from the deep wells in the Middle Lias was found to be insufficient. Still deeper wells were made in the hopes of reaching water-bearing Triassic rocks; but these were failures.

Mr. Thompson has for some years past advocated that a system of dumb-wells be constructed—about 100 feet in depth on the average. "These dumb-wells would all be situated in the valleys, and would generally require to be cut through a little alluvium and river gravel, and through the Upper and Middle Lias. The wells might be lined with brick, and then filled up with coarse gravel, broken brick, or any good porous material to within 35 ft. or 40 ft. of the top, the material to get finer towards the top, in imitation of the filter beds of the London water companies. The depth of 35 ft. to 40 ft. not filled with gravel is given to enable the water running in from the river gravel, as well as that from the surface, where such water is desirable, to have a good fall, whereby it may be effectually aerated before entering the chief filter bed."

The author would take advantage of the river gravel as a primary reservoir and filter-bed, whence the water would be conveyed into the Marlstone. He mentions that at the present time water obtained from the river gravel is clear, and free from suspended impurities, and would still be so if his plan were adopted, so that, in his opinion, there would be little or no silting up of the dumb-wells. Additional supplies of water might also be obtained from the river by means of pipes when the water was sufficiently high for it to be well spared, and this would tend to prevent the injuries that arise to the banks from overflowing. The author, therefore, contends that his scheme, of which he gives full details, would improve a large district now injured by floods; it would furnish an abundant water supply in a natural reservoir (the Middle Lias); and the water would be very pure, because it would be filtered before entering the well, and filtered again in the well before entering the most effectual filter the Marlstone itself, while it would be well aerated by its fall.

Various objections have been raised against this scheme, and these are fully discussed by Mr. Thompson. Perhaps the most serious objection is that a scheme of this nature has not been tried before in this country, and that it must necessarily be an experiment. Such an objection might have been urged against some of our deep borings! Another question is whether the water would go away through the dumb-wells. Water obtained from old wells was of an artesian nature rising formerly at one place 90 feet above the water-bearing rock. This, however, was before the water-level had been reduced by the large supplies procured, and so long as large supplies are pumped up, there would be no danger of overflow from the dumb-wells. The dip of the beds is considered too slight to offer any obstacles to the scheme. The Upper Lias is 170 to 190 feet thick, and the author calculates that there could be a head of water of 110 feet at Northampton, before the dumb-wells would cease to act or occasion loss.

The scheme, however, was not adopted by the Town Council of Northampton—as it was considered too theoretical by the "practical" men; moreover it was deemed necessary to procure a supply without loss of time, and an artificial reservoir to hold 400 millions of gallons of water has been constructed near Ravensthorpe. Mr. Thompson claims that his plan, if successful, would have saved the town at least £75,000; hence it seems a pity that it was not given a trial by the construction of one or more experimental dumb-wells, for we feel confident that the plan could not have been proposed under geological conditions more likely to prove favourable to its success.

Those occupied in the subject of water-supply will, however, find in this carefully-prepared work much matter of interest and instruction; and the author need not feel that his labour has been unproductive of good, even if he has not been considered as a "prophet" in his own country.

II.—Dr. C. Forsyth-Major's Palæontological Discoveries in the Isle of Samos.

Sur un Gisement d'Ossements Fossiles dans l'Île de Samos, contemporains de l'âge de Pikermi. Par M. Forsyth Major. *Comptes Rendus*, vol. cvii. pp. 1178–1181 (1888).

THIS paper contains a preliminary notice of a collection of Vertebrate remains of Lower Pliocene age obtained by the author during the year 1887 in the island of Samos in the Turkish Archipelago. Among these are a large number of forms specifically identical with the mammals from the equivalent deposits of Pikermi in Attica, Baltavar in Hungary, and Maragha in Persia; but there are also some new types, which are of interest either from a distributional or a purely zoological point of view.

Among these new forms is a species of Ant-bear (*Orycteropus*), which is the only representative of that genus yet known beyond the Ethiopian region. A large Pangolin, which is estimated to have been nearly three times the size of the West African *Manis gigantea*, is made the type of the new genus *Palæomanis*; and is of interest as showing how the African Pangolins may have been connected with those of India.

Perhaps the most striking new type is a large ruminant referred by the author to the *Giraffidæ*, and stated to connect *Helladotherium* and the Giraffe with some of the aberrant Antelopes of Pikermi. Finally a large Ostrich is especially noteworthy from a distributional point of view, since we now have remains of this genus from Samos, the Thracian Chersonese, and Northern India. R. L.

Note.—We learn that Dr. H. Woodward has just returned (20 August) from Florence, having secured Dr. C. Forsyth-Major's valuable collection from Samos for the British Museum (Natural History), Cromwell Road, to which it will doubtless prove a most important addition.